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WEEKLY April 15-21, 2017

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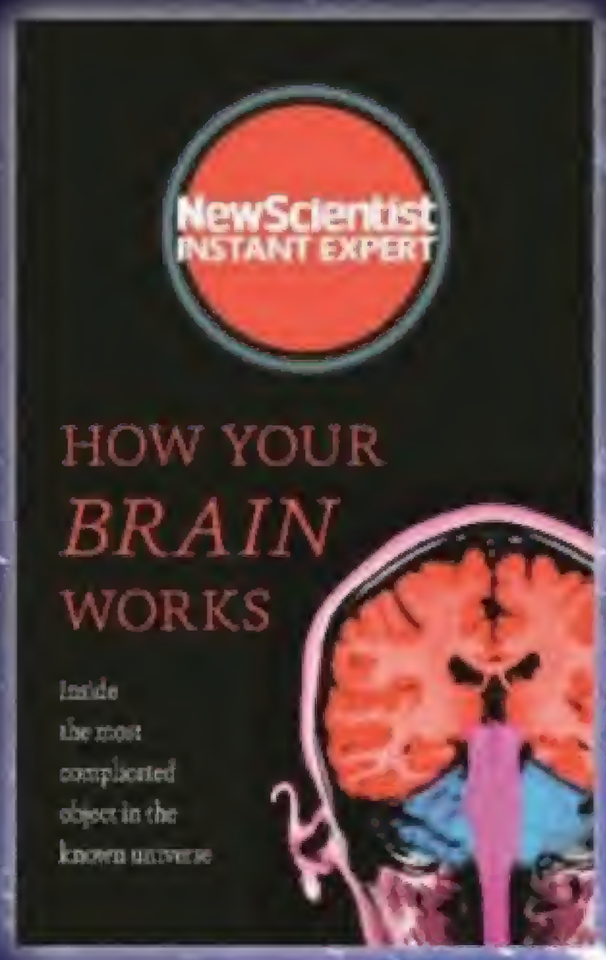

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Holier than thou?

It's time atheists embraced the science of religion

IT IS just over a decade since Richard Dawkins lit the blue touchpaper with his book *The God Delusion*. It introduced much of the world to the so-called new atheism – a forceful rejection of religion based on the premise that scientific materialism offers a superior explanation of the universe, while religion is a corrosive influence on society: a pathological meme planted in the minds of defenceless children.

Though a great read and a liberating influence for many closet atheists, *The God Delusion* largely omitted a new strand of scientific enquiry emerging around the time it was published. Those working on the "science of religion" – a motley crew of psychologists, anthropologists and neuroscientists – explained it as a by-product of normal cognition. Thanks to evolution, they argued, our explanation-seeking minds find religious ideas intuitively appealing, gobbling them up as a hungry trout swallows a fishing fly.

To many disciples of the new atheism, this was little more than, well, heresy. They decried it as "accommodationism" – an illogical and often harmful attempt to pretend religion can still serve a purpose now that science rules the roost. Never mind that the cognitive by-product theory does not imply that religious beliefs are true – far from it. Nor does it claim religion and scientific materialism are compatible. It merely attempts to explore religious belief and disbelief using the tools of science, rather than rhetoric.

The new atheists attacked it anyway. In terms of public debate around the appropriate role of religion in society, this was a mistake. It alienated as many people as it won over, leaving the new atheists preaching to the converted, polarising the debate and dissuading moderates of both secular and religious persuasions from getting involved at all.

"Tarring militants with their own brush undermines atheists' claim to occupy the intellectual high ground"

Perhaps most damagingly, it fostered an idea already doing the rounds: that atheism is a belief system whose adherents can be as blindly dogmatic as any other. In other words, that it is "just another religion".

At first glance this has all the sophistication of a playground taunting match: you smell. No, *you* smell. But as a rhetorical device it is highly effective. Tarring militant atheists with their own brush undermines their claims to the intellectual high ground, and when it came to some of the new atheists, it had the ring of truth to it. But is it really true of all the godless?

Once again, those practising actual science offer answers. The science of atheism, brought to you by the people who brought you the science of religion, says that atheism really isn't just another religion but something altogether different – although not for the reasons you may think (see page 32). No doubt militant atheists will say "we knew it all along"; but perhaps they will also find some common ground with those they had dismissed as apologists.

Or perhaps not. The science of religion challenges core elements of the new atheism: for example, the belief that religion leads on the whole to misery and suffering. Belief-ologists say religion was the "social glue" that held early societies together (17 March 2012, page 42). That doesn't mean religion is required to play that role today. But simply ignoring or high-handedly dismissing its power will not abolish its sway or further the secularist cause. And given the rise of religiosity in global affairs, there is much more than a rhetorical joust at stake. ■

MOHAMMED KARKAS/ANADOLU AGENCY/GETTY IMAGES

Innocent victims

Syria's chemical game

THE Syrian conflict has entered an ominous new phase, with the US firing cruise missiles at a Syrian air base from which a massive chemical attack was launched last week.

At least 86 people were killed and hundreds more wounded when chemical weapons rained down on the northern rebel-held town of Khan Sheikoun. Samples from victims and the attack site are still being analysed but early autopsies show that sarin was to blame, say Turkish authorities.

In response, the US fired cruise missiles at the Shayrat airbase, where sarin had been previously stored, and from which US radar tracked the attacking aircraft last week.

Sarin, an illegal weapon, was last used on such a scale by the Assad regime in 2013, in Ghouta, near Damascus, when 1400 people died. That time, the US abandoned threats of military action when Russia, Syria's ally, joined it in forcing Assad to sign up to the international treaty banning chemical weapons, and to destroy the country's stockpile.

But Assad has continued to use chemical weapons, launching around 100 chlorine attacks. There have also been unconfirmed reports of smaller sarin attacks.

Russia denies the regime used chemical weapons, claiming Syrian rockets hit a store of rebel-held sarin. But sarin would not have been kept in its finished, toxic form, says Ralf Trapp, a former consultant at the Organisation for the Prohibition of Chemical Weapons. And if it was, the blast would have destroyed it.

Wacky spacers

THE ideas sound like science fiction, but NASA is putting its weight behind them. Last week, the agency announced funding for 22 technology proposals under its NASA Innovative Advanced Concepts programme.

"A robot shaped like a floppy frisbee would stick to a nearby asteroid, then launch rocks from it"

NIAC allows space researchers to pursue their so-crazy-it-just-might-work ideas. This year, 15 proposals got phase I funding of about $125,000 each, and seven projects that have made it through phase I got a second cash infusion.

Several phase I winners relate to how we propel spacecraft. One, "A breakthrough propulsion architecture for interstellar precursor missions", proposes using a space-based laser to beam power to fast craft exploring our solar system and beyond.

Others present innovative ways to explore worlds. "Pluto hop, skip, and jump" is a proposed lander that will take advantage of Pluto's low gravity to leap kilometres at a time, taking measurements as it goes. Then there's "Dismantling rubble pile asteroids with area-of-effect soft-bots". It will use a robot shaped like a floppy frisbee that would stick to a nearby asteroid, launching rocks from it to be caught by another craft in orbit.

All the projects that won NIAC funding are still at an early stage – it will be a decade or longer before any of them might be used in an actual mission.

Planet finders

AFTER just two days, volunteer scientists taking part in a planet-hunting project have discovered four super-Earths orbiting a sun-like star. This brings the count of stars with four or more planets up to 74.

Zooniverse's Exoplanet Explorers project allows citizen scientists to scour data from the Kepler spacecraft via their home computers. When planets pass between their stars and us, they block some of the light, creating a dip in the star's light curve. The volunteers identify light curves with a repeated dip each time a planet orbits.

This new planetary system, 597 light years away in the constellation Aquarius, has dips from four different planets. The planets take only 3 to 13 Earth days to orbit their star. The smallest is just shy of twice Earth's size, and the largest is 2.74 times as big.

Since the project began on 4 April, citizen scientists have classified more than a million light curves and found 184 potential planets – 53 of them categorised as super-Earths.

MONICA ALMEIDA/THE NEW YORK TIMES/EYEVINE

Deep trouble

Radiation Plan B

PRESIDENT TRUMP has revived controversial plans to bury the US's stockpile of radioactive waste in tunnels dug into Yucca Mountain in Nevada. But with local opposition undimmed, a backup option is also being tested.

The US has some 79,000 tonnes of spent fuel in at least 76 power-station cooling ponds and dry stores across the country. Another 2000 tonnes are added each year.

Last month, Trump asked

Congress to approve $120 million to resume the licensing process for Yucca Mountain. But Nevada's governor and senators vowed to continue blocking the plan, as they have done since 1998.

So the Department of Energy is working on an alternative. It plans to bury the spent fuel in hundreds of narrow shafts drilled 5 kilometres down into solid granite across the US. The technique has yet to be tested, but the idea is that the waste would melt surrounding rock and then slowly solidify into a granite "coffin".

The first test drilling site is set to be announced next month.

Alzheimer's test

PEOPLE in the US will soon be able to buy a genetic test that tells them whether they are at risk for late-onset Alzheimer's disease.

The saliva-based test is being marketed by 23andMe, based in California. The firm already offers "spit kits" for US-based customers who want to trace their ancestry or to know their risk of passing on genetic diseases to their children.

But in 2013, the Food and Drug Administration banned 23andMe from offering a test that assessed genetic risk for 254 diseases. The FDA was especially concerned by the test's assessment of breast cancer risk – a false positive might encourage a person to get unnecessary surgery, while a false negative might lead someone to ignore symptoms.

The new test won't assess breast cancer risk, but will screen for Alzheimer's, Parkinson's, coeliac disease and seven other disorders. The FDA's approval was largely based on studies and trials that show these conditions are linked to genetics, and the fact that the test is at least 99 per cent accurate.

23andMe already markets a similar product in seven countries, including the UK.

Stop revenge porn

FACEBOOK is to use photo-matching technology to help prevent the spread of revenge porn on its platforms.

Revenge porn is the sharing of private sexual images without the subject's consent. Any images reported to Facebook will now be reviewed and removed by "specially trained representatives" from the community operations team, says the firm. In most cases the account that shared the image will be suspended.

Photo-matching technology will be used to help thwart further attempts to share the same image across Facebook's apps, which include Messenger and Instagram. "If someone tries to share the image after it's been reported and removed, we will alert them that it violates our policies and that we have stopped their attempt to share it," says Antigone Davis, Facebook's head of global safety.

The new process will provide reassurance for many victims and reduce the amount of harmful content on the platform, says Laura Higgins, founder of the Revenge Porn Helpline in the UK. "We hope that this will inspire other social media companies to take similar action and that together we can make the online environment hostile to abuse."

Barrier Reef's worsening plight

IT GOES from bad to worse for Australia's Great Barrier Reef.

The northern third of the reef was severely bleached in 2016. In places, two-thirds of the corals died during that event, a team at James Cook University in Townsville, Australia, reported recently. Last week, the same team announced that the central portion of the reef, a major draw for tourists, is now suffering a similar fate.

In 2016, the bleaching was caused by El Niño, which warms surface waters. But this year's bleaching is occurring during a so-called "normal" year without such an event.

"The water is just too damn hot," says Terry Hughes, the leader of the survey. Hughes flew over the worst-affected area in a small aircraft to investigate the extent of bleaching on the reef, which started to be noticeable in early February. Nearly 200 divers have also been documenting the destruction.

It will take up to nine months to find out how many of the bleached corals end up dying, but Hughes fears that the central reef may have been nearly as badly damaged this year as the northern part was last year.

"Our combined 2016 and 2017 surveys show that two-thirds of the Great Barrier Reef has now been badly degraded," says Hughes. "Now that bleaching is happening every year or every other year in some areas, recovery will be difficult if not impossible."

GREG TORDA

Beyond repair?

60 SECONDS

Squid RNA trickery

Octopuses and squid can edit their own genetic instructions. By interfering with RNA transcripts of their DNA, their cells are able to make a wider variety of proteins (*Cell*, doi.org/b5gx). This may allow them to undergo a special kind of evolution, one not based on DNA mutations.

Turbulence ahead

Air travel could get a lot bumpier by the middle of this century, thanks to climate change's effect on jet streams. Supercomputer modelling suggests that a doubling of carbon dioxide in the atmosphere could lead to hazardous turbulence on commercial flights becoming two or even three times as common as today (*Advances in Atmospheric Sciences*, doi.org/b5gz).

Cause for alarm

Hackers took control of all 156 emergency sirens in Dallas, Texas, on 5 April. The city's alarms, which usually warn of dangerous storms and tornados, were triggered at around 11.40 pm and blared until about 1.20 am, when the system was turned off. Officials say they believe the hacker was in the Dallas area.

Renewables on the rise

The world enjoyed a record gain in new renewable power generation last year, according to a report compiled by UN Environment and several other organisations. Wind, solar, biomass, geothermal, small-scale hydropower, marine energy and waste-to-energy schemes added 138.5 gigawatts to global power capacity in 2016, up 8 per cent from 2015.

Night owl gene

A variant of a circadian clock gene may explain why some people prefer to stay up late. A mutation in this gene correlates with an extended circadian cycle in 39 people in Turkey (*Cell*, doi.org/b5g2), who tend to go to sleep 2 to 4 hours later than those without the mutation.

Dark energy flipped upside down

Has cosmology muddled cause and effect, asks **Anil Ananthaswamy**

OUR universe's relentless march towards cold, empty darkness could be causing its expansion to accelerate, rather than the other way around. The finding could help cosmologists think differently about dark energy, and possibly explain why it has the value it does.

In the late 1990s, astronomers observed that the universe's expansion is accelerating. They attributed this to dark energy – an inherent property of the vacuum of space-time.

One idea is that dark energy is really the cosmological constant, a quantity arising in Einstein's general relativity. But when we calculate its theoretical value, the answer is about 120 orders of magnitude larger than the observed one. The mismatch has vexed cosmologists for decades.

"Why does the cosmological constant have the value it does? Why is it so small?" says Sean Carroll at the California Institute of Technology in Pasadena.

"Dark energy emerges from quantum space-time, and then drives the accelerated expansion of the universe"

Although they can't solve that yet, Carroll and his student Aidan Chatwin-Davies suggest we could make headway using something quite different: the laws of thermodynamics. "We are contributing to a movement to change that question to something else," says Carroll.

We have had an idea of the universe's end state since 1983, when Robert Wald of the University of Chicago showed that a universe with a positive cosmological constant will end up as a flat, empty, featureless void, called de Sitter space.

Wald did this using general relativity. But some physicists had long suspected that you could reach the same end state using thermodynamics.

The link with thermodynamics also dates back to the 1980s. Tom Banks at the University of California, Santa Cruz, suggested then that the value of dark energy could be related to the entropy of space-time. Entropy is a measure of the disorder of a system: it's low for a solid with rigidly organised atoms, and high for a hot gas with chaotically moving atoms.

What if the system is "closed", in that it can't exchange energy with its surroundings? According to the second law of thermodynamics, its entropy will keep growing until it reaches an equilibrium. If we regard the entire universe as closed, the law suggests that it too will eventually reach a state of peak entropy and just stay there.

That sounded a lot like de Sitter space to Carroll and others. Having a thermodynamic route to the same universal end game could help break the stalemate over the mismatch problem. But they couldn't prove the route existed.

Some clues came from black-hole physics. In 1974, Israeli physicist Jakob Bekenstein showed that the entropy of a system containing a black hole and its immediate environment grows – a result now called the generalised second law of thermodynamics.

Missing ingredient

This hinted that the final state of the universe predicted by general relativity was related to growing entropy. "The missing ingredient was some way of formulating the [generalised] second law in a way that was applicable to the whole universe all at once," says Carroll.

That came last year, when Raphael Bousso at the University of California, Berkeley, and Netta Engelhardt, now at Princeton University, applied Bekenstein's idea to a patch of space-time in an expanding universe like ours. They conjectured that its entropy increases.

Carroll and Chatwin-Davies took Bousso and Engelhardt's definition of entropy – which uses a quantum mechanical description of space-time – as their starting point. They then calculated what happens to the geometry of space-time as it evolves. Lo and behold, once a universe has reached peak entropy it is effectively one described by de Sitter geometry, they proved (arxiv.org/abs/1703.09241).

"The universe will approach de Sitter space and stay there forever," says Carroll.

Bousso is impressed. "This is a beautiful application of our cosmological second law," he says.

This thermodynamic way of thinking turns the standard view of dark energy on its head: dark energy emerges from the quantum structure of space-time and then drives the accelerated expansion. Solving the mystery of dark energy's value then becomes a case of justifying the choice of a particular quantum mechanical description of space-time.

Carroll is careful not to overstate the implications. "There's what we proved, and there is the coffee-shop chatter about what it might imply, which is of course much more speculative," he says. But the work could offer a new way to grapple with the cosmological constant's tiny value. ■

NASA, ESA, H. TEPLITZ AND M. RAFELSKI (IPAC/CALTECH), A. KOEKEMOER AND Z. LEVAY (STSCI), R. WINDHORST (ARIZONA STATE).

Built to expand ever faster?

Reprogrammed cells may ease Parkinson's

USING a virus to reprogram cells in the brain could be a radical way to treat Parkinson's disease.

People with Parkinson's have difficulty controlling their movements due to the death of neurons that make dopamine, a brain signalling chemical.

Transplants of fetal cells have shown promise for replacing these dead neurons in people with the disease, and a trial is currently under way. But the transplant tissue comes from aborted pregnancies, meaning it is in short supply, and some people may find this ethically difficult. Recipients of these cells have to take immunosuppressant drugs too.

Ernest Arenas at the Karolinska Institute in Stockholm, Sweden, and his team have found a new way to replace lost dopamine-making neurons. They injected a virus into the brains of mice whose dopamine neurons had been destroyed. This virus had been engineered to carry four genes for reprogramming astrocytes - the brain's support cells - into dopamine neurons.

Five weeks later, the team saw improvements in how the mice moved (*Nature Biotechnology*, DOI: 10.1038/nbt.3835). "They walked better and their gait showed less asymmetry than controls," says Arenas.

This is the first study to show that reprogramming cells in the living brain can lead to such improvements, says Arenas.

The team has also used the same four genes to convert human astrocytes into dopamine neurons in a dish, suggesting that a technique like this may be possible in people.

"The critical question will be whether this would work in the aged human brain, and generate enough dopamine cells of the right type that can connect up with the brain in the same way that transplanted dopamine cells can," says Roger Barker at the University of Cambridge, who is leading the fetal transplant trial. Andy Coghlan ■

MAURO FERMARIELLO/SPL/GETTY

The goal is to roll your own

Race to automate all-round fingerprinting

THE US government wants a better way to get its hands on people's fingerprints – and it has set up a contest to find it.

The Intelligence Advanced Research Projects Activity (IARPA) has launched a challenge that pits security companies and research groups against each other, in a bid to build a device that accurately captures every part of a fingerprint. This "nail-to-nail" scan covers the whole fingertip, from one side of the fingernail to the other. It is the gold standard, giving police officers more chance to match a partial print found at a crime scene, for example.

But capturing prints like this is time-consuming and labour-intensive, says Chris Boehnen at IARPA, who is managing the contest. At present, a security officer must roll a person's fingers across a surface, one at a time. Because of this, the US only uses nail-to-nail fingerprinting when someone is taken into police custody or has a background check for security clearance. At airports, arriving passengers simply have a "flat" fingerprint taken. This only captures the central part of the fingerprint, but can be done with a scanner.

IARPA wants to find an automated way of capturing nail-to-nail prints, to make the process easier, quicker and less prone to human error. "Human beings are the weak link in performance," says Boehnen. Errors can creep in if an officer doesn't roll someone's finger correctly, but it's nearly impossible for humans to recreate the exact same motion each time.

"A system that sees under the skin could thwart people altering their prints by burning their fingers"

Automating the process would help ensure a consistently high standard, he says.

Fourteen teams have already started building nail-to-nail systems, with a top prize of $100,000 on offer for the best overall entry as well as smaller prizes for speed and accuracy. Competing teams that get through the first round of evaluation in July will bring their system to a live test in Maryland in September. Over one week, they will use their system on 300 people, and the results will be compared with those from the best human-operated nail-to-nail schemes.

The winning system must be capable of automatically capturing fingerprints 90 per cent of the time, and be no more than 20 per cent slower than human-operated alternatives.

Competitors are adopting a range of approaches. Amit Lal at Cornell University in Ithaca, New York, and his team are using pulses of ultrasound emitted from a glove. The user will wear the glove, and a scanning chip in the fingertip will then measure minute variations in the reflected waveforms to create an image of the finger. "The real advantage of ultrasound is that it can go deeper in the tissue to get sub-tissue features like blood vessels and sweat pores," says Lal.

Being able to see beneath the skin could help thwart fingerprint "spoofing", he says, in which people alter their prints by burning their fingers or wearing a thin layer of gelatin with a different fingerprint on it.

Daniel Raguin at biometrics company Crossmatch is more tight-lipped about his team's approach, but says it will be based on their existing optical technology, using a light sensor similar to that in a digital camera to take an image of a finger placed against a glass panel. Most current flat fingerprint scanners use this approach.

If someone cracks the challenge this year, Boehnen plans to announce the result at a biometrics conference in London in November. But it may take longer to develop a device that meets all of the contest specifications. "It is highly possible that no one will win the grand prize in the first year," he says. **Matt Reynolds** ■

Sleep signature reveals how much we dream

YOU dream more than you know. A new way to detect dreaming has confirmed that it doesn't only occur during rapid eye movement (REM) sleep, and has shown why we often don't remember our dreams.

"There is much more dreaming going on than we remember," says Tore Nielsen at the University of Montreal, Canada. "It's hours and hours of mental experiences and we remember a few minutes."

During sleep, low-frequency brainwaves are detectable across the brain. Now Francesca Siclari at the University of Wisconsin-Madison and her colleagues have discovered that a decrease in these waves in an area at the back of the brain is a sign that someone is dreaming.

"This zone was a little bit more awake, showing high-frequency brainwaves more common during wakefulness," says Siclari. This one region seems to be all that's necessary for dreaming, she says.

Siclari's team found this dream signature by using EEG caps to map the brain activity of 32 people while they slept. The team woke the sleepers when they showed various patterns of brainwave activity, and asked them if they had been dreaming.

Some participants reported having dreams with a narrative structure, while others were more impressionistic. The experiment seems to have had an influence for some. "One had a dream about reporting a dream," Siclari says.

The team found such a strong correlation between dreaming and fewer low-frequency waves in the "hot zone" that they could successfully predict whether a person was dreaming 91 per cent of the time (*Nature Neuroscience*, DOI: 10.1038/nn.4545).

The researchers then used this sign of dreaming to investigate how our brains behave as we dream. We normally associate dreams with REM sleep, and the team saw that dreams during this phase were linked to a rise in high-frequency brainwaves in areas that are active in waking hours. This activity matched the brain areas that would have been active if the dreamers had been living out their dreams in real life.

The dream signature also revealed how much we dream during non-REM sleep. Monitoring seven people over five to 10 nights of sleep, Siclari found the volunteers dreamed during 71 per cent of their non-REM sleep, in addition to 95 per cent of their REM sleep.

Despite all this dreaming, many dreams are forgotten. Sometimes participants had a foggy idea they had been dreaming, but couldn't remember what about. In a further experiment with 10 people, the team found that being able to later remember a dream was linked to higher activity in the prefrontal cortex – which is associated with memory – while dreaming. "The region for remembering the dream was different from the region for having a dream," Siclari says.

Christoph Nissen, at University Psychiatric Services in Bern, Switzerland, says the team's mapping of dreaming brain activity could lead to ways of modulating our perception of sleep or even manipulating our dreams – perhaps using transcranial direct-current stimulation to alter dream-associated brainwaves.

"There's treatment potential here for people who have non-restorative sleep, like those with insomnia, or nightmares from PTSD," says Nissen. "You might think about evoking the dream state or suppressing dream states, and even combine these interventions with psychological techniques to improve the perception of sleep in the case of insomnia, or to improve nightmares." Chelsea Whyte ■

LAWREN/GETTY

But will they remember?

Life could exist up to 10 km below sea floor

LIFE might eke out an existence far deeper inside Earth than we imagined. Samples from a mud volcano contain biological signatures that suggest microbes lived in the material when it was several kilometres beneath the ocean floor.

"We might have a very big biosphere below our feet that's very hard to get to," says Oliver Plümper of Utrecht University in the Netherlands.

Other researchers agree life could exist at such depths, but say the case is not yet proven. "They don't have conclusive evidence," says Rocco Mancinelli, an astrobiologist at NASA's Ames Research Center, who studies life in extreme environments.

Plümper's team studied 46 samples drilled from the South Chamorro mud volcano, near the deepest part of the ocean, the Mariana trench. Here, one tectonic plate slides under another. The heat and stress causes some of the material on the subducting plate to become a buoyant mineral called serpentinite that rises and erupts out of mud volcanoes.

Examining the serpentinite in their samples, the team found chemicals usually produced by life, including amino acids and hydrocarbons.

Given that some microbes can withstand temperatures as high as 122°C and pressures about 3000 times higher than at Earth's surface, Plümper calculates that life could survive up to 10 kilometres beneath the seabed (*PNAS*, DOI: 10.1073/pnas.1612147114).

"We might have a very big biosphere deep below our feet that's very hard to get to"

There have been several recent reports of life at great depths, with nematode worms found living 3 kilometres down in a gold mine, for instance. But if Plümper is right, life can survive far deeper still.

Mineral reactions at these depths would provide the carbon, nitrogen and energy life needs, says Mancinelli. But the chemicals found by Plümper's team might have been produced by processes that don't involve life, he adds. Chelsea Whyte ■

Wealth can't always buy health

Jessica Hamzelou

INEQUALITY is at a historic high in the US, driving a huge health gap between rich and poor. But wealth is only part of the story – racism means that even minorities on a high income have worse health.

"Income inequality has increased dramatically, to levels not seen since before the Great Depression," says Jacob Bor at Boston University, Massachusetts. His team has reviewed research on the life expectancies of the richest and poorest in the US between 1980 and 2015. They found that not only is the health gap growing, but health is becoming more strongly linked to financial status (*The Lancet*, doi.org/b5cv). "Your income matters more for your health than it did a decade ago," says Bor. "Poverty is becoming a more important risk factor for early death."

"Rich black people still had more health disadvantages compared with rich white people"

US life expectancy is three years lower than Canada's. One factor is lack of health insurance: 27 million people still don't have coverage. Even those who do can still struggle to afford treatment, as insurance plans don't always cover all costs (see graph, right).

But there are many other reasons why poorer people have worse health, says Bor. They tend to get less education, are more likely to be out of work, and are at greater risk of substance abuse and self-harm as a result. Richer people can afford better insurance, live in neighbourhoods with abundant green spaces and can more easily afford to eat well.

But a high salary can't buy good health for everyone. African Americans have a shorter average lifespan, and are at higher risk of developing and dying from cancer and heart disease.

Kanetha Wilson at Vanderbilt University in Nashville, Tennessee, and her team analysed data collected between 2000 and 2011 from more than 2500 people who earned $175,000 at the start of the study – more than four times the average salary that year (*Preventative Medicine*, doi.org/10/b487). "We found that black people still had more health disadvantages compared to white people," says Wilson. "They had greater odds of having hypertension, lower mental health and obesity."

Wilson thinks everyday racism may be part of the problem. "As a black woman, I know that just because you're on a high income, doesn't mean that people won't treat you differently," she says.

Chronic exposure to "microaggressions" – including subtle put-downs that make people feel undervalued, criminal or foreign – are known to cause mental health problems.

KEN CEDENO/GETTY

Money isn't the whole story

But structural racism is also problematic, writes Zinzi Bailey at the New York City Department of Health and Mental Hygiene and her team in a separate study. Reviewing all the studies on racial discrimination and health in the US published so far this century, they found that segregation is endangering lives.

The average white American lives in an area that is 75 per cent white, while the average black American lives in areas that are only 35 per cent white. These areas tend to have lower-quality housing and greater exposure to toxins and crime – all of which are linked to poor health or early deaths (*The Lancet*, doi.org/b5cw).

The team also found that crime policy disproportionately targets black people, despite illicit drug use being at similar levels among both black and white groups. One study showed that by 2014, almost 3 per cent of all black men in the US were serving prison sentences of at least one year.

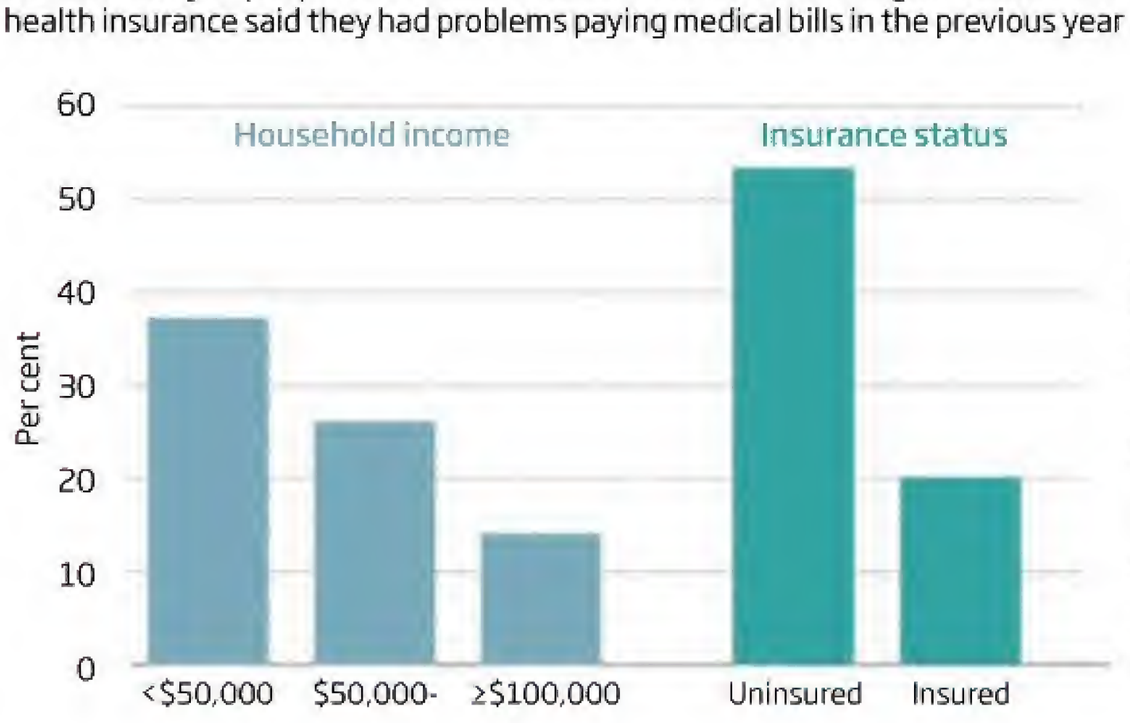
This has far-reaching consequences. A review suggests that the long-term health of people who have been in prison is much worse, but it doesn't stop there. Nearly half of all black women in the US have a relative in prison. These women are more likely to develop mental health problems and cardiovascular disease, while their children are at a greater risk of early death (*The Lancet*, doi.org/b5cx). Daughters of people in prison in particular are prone to weight gain.

Drug sentencing reforms and more health insurance may help. But people also need protection from poverty, says Bor. "It's about ensuring everyone has access to safe housing and healthy food."

However, President Donald Trump plans to cut food vouchers for poor women and children and repeal the Affordable Care Act, also known as Obamacare. "We will likely see these gaps continue to widen," says Bor. ■

Health cost woes

A 2016 survey of people in the US found that even those with higher incomes or health insurance said they had problems paying medical bills in the previous year



SOURCE: KAISER FAMILY FOUNDATION/NEW YORK TIMES

Ecstasy boosts people's trust

Clare Wilson

ECSTASY makes you feel like everyone's your friend. Now an experiment in which people played a trust game after taking the drug is helping to explain why.

Also called MDMA, ecstasy is known to trigger the release of the brain chemical serotonin, as well as mimicking its actions in the brain. Investigating how this affects us could help us understand how we govern our social actions, and how this process goes awry in depression and schizophrenia, says Anthony Gabay at King's College London.

In their latest study, Gabay and his team gave 20 men MDMA and asked them to play a game called Prisoner's Dilemma on a computer while lying in a brain scanner.

The points earned in the game depend on whether you cooperate with or betray your opponent, and on what they choose to do. The game gets more complex if played over a number of rounds, because while you earn the most points on a single round by betraying your opponent, you earn more over time if both people cooperate.

The men played 15 rounds of the game with the same opponent, allowing relationships to build – although unbeknown to them, they were playing against a computer.

When they were given MDMA, they became euphoric and talkative. "Some of them wanted to hug me," says Gabay. In this state, they cooperated twice as often as when they had played the game after being given a placebo – if their opponent was usually trustworthy.

But if their opponent usually betrayed them, the men acted the same way regardless of whether they had taken MDMA or a placebo, playing less cooperatively. "They were nice but not stupid," says Gabay. The results were presented at the British Neuroscience Association conference this week.

Brain scans the team took showed that MDMA boosted activity in several brain areas linked to social behaviour, including the right superior temporal sulcus. Recent work has shown the serotonin receptor that is activated by MDMA is found at the highest concentrations in the superior temporal sulci on both sides of the brain, as well as the other areas that became more active in this study.

Michael Mithoefer at the Medical University of South Carolina says the findings help shed light on what MDMA does. "There's a lot we still don't know."

Mithoefer is investigating ecstasy as an aid for treating post-traumatic stress disorder. It may help people trust their therapist more and prevent them from being overwhelmed by their traumatic memories during therapy, he says. ■

HECTOR MEDIAVILLA / PICTURETANK

Feeling euphoric

Giant virus may just be a small-time crook

MYSTERIOUS microbes that some consider a whole new domain of life may just be normal viruses that pilfer genes from their host organisms.

The conclusion is, however, hotly contested by scientists who identified the first recognised giant virus in 2003.

Unlike normal viruses, say HIV, which are tiny and only have a few genes, giant viruses have hundreds of genes and can be almost as large as bacteria. This is one exotic feature that has perplexed microbiologists studying their origins.

But a study now argues that these microbial giants are just small viruses that grew large by stealing genes from their hosts – rather than evolving separately.

Frederik Schulz at the US Department of Energy Joint Genome Institute and his colleagues found evidence of a new giant virus in a waste-water treatment tank in Klosterneuburg, Austria, when analysing all the genetic material in samples of water. So far, they haven't succeeded in isolating the virus inside a host cell, so we don't yet know what its host is. Surprisingly, about 700 of its genes are shared with a multitude of different cellular organisms (*Science*, doi.org/b5cr).

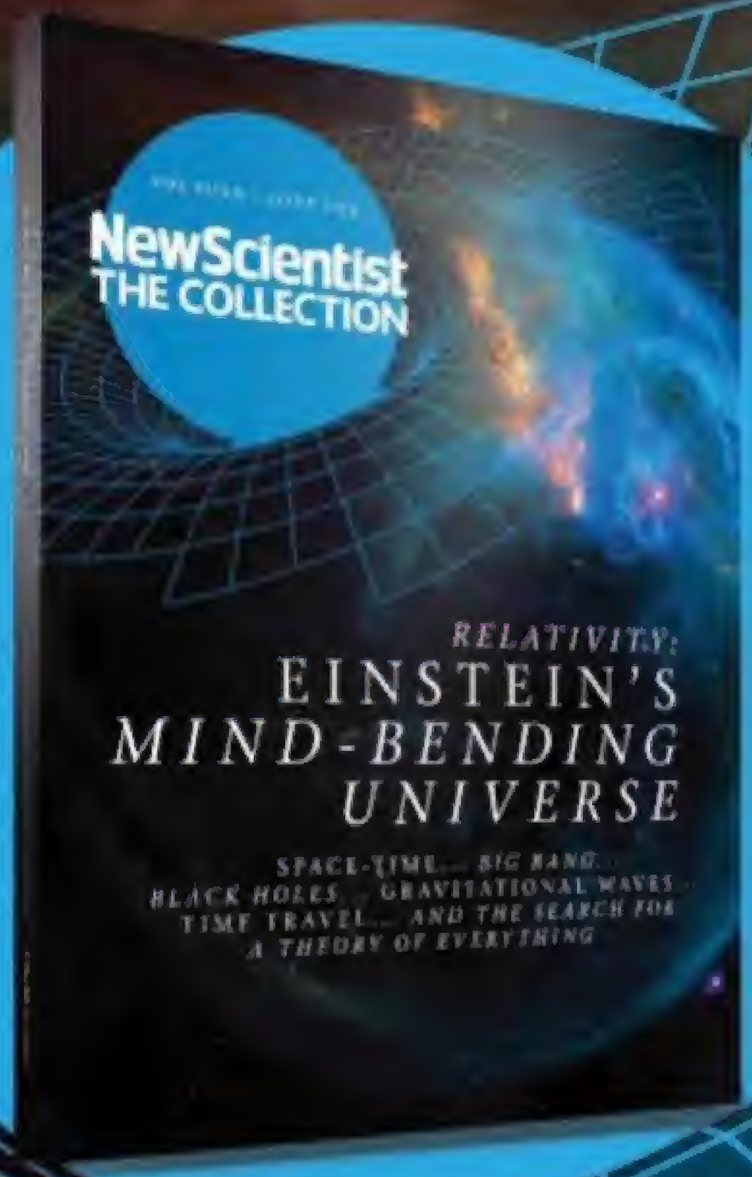
That finding suggests the virus stole those genes from its hosts, says Schulz, which he thinks may explain how other giant viruses grew so big too. "This is the ultimate evidence that the virus acquired these genes from different eukaryotic cells," he says. In other words, giant viruses might have changed our notion of what viruses can be like, but they don't require us to rewrite the story of life just yet.

Others are unconvinced, though.

"This is the ultimate evidence that the giant virus stole many genes from more advanced cells"

Jean-Michel Claverie at Aix-Marseille University in France, who was in the team that found the first giant virus, argues for their treatment as a separate category of life. He says that analysing genes all mixed up in the sample – the method that Schulz's team used – is prone to generating "chimeric" genomes made up of material from several organisms.

He adds that the idea of small viruses becoming big breaks a general law of biology, because parasitic microbes tend to lose genes and get simpler over time. "I am waiting to see a real virus isolated with its host before I believe any of their evolutionary interpretations," he says. Sam Wong ■



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Dinner is served

Microbes help lock up nuclear waste

Sam Wong

LET them eat waste. Bacteria could thrive on nuclear waste dumped deep underground and immobilise it to make it safer.

Certain microbes can use radionuclides such as uranium and neptunium in place of oxygen, studies have found. In doing so, they convert them from soluble to insoluble forms, making them less mobile.

This should give us more confidence in waste disposal plans, says Jonathan Lloyd, a geomicrobiologist at the University of Manchester, UK, who presented the research at the annual meeting of the Microbiology Society in Edinburgh last week.

The UK has accumulated around 4.5 million cubic metres of nuclear waste, enough to fill London's Wembley stadium four times. Most of it is currently stored in ponds and silos at surface level at Sellafield in Cumbria. The government plans to dispose of the most highly active waste deep underground, in repositories encased in cement, but has yet to decide on a site. These plans take into account physical and chemical properties to stop radioactive material from escaping for hundreds of thousands of years – but not biological.

It had been thought that the presence of cement would result in conditions too alkaline for microbes to grow – it has a pH of around 11, similar to bleach. To see if this was so, Lloyd's team studied a lime kiln site in the UK's Peak District to see if microbes could be found growing in conditions

"Radiation levels found at nuclear waste dumps don't kill these bacteria, they stimulate them"

similar to those that would be expected in a nuclear disposal site. "We went to see if there was biology there and there was," says Lloyd. "We found they could grow at pH values you would probably find developing around these cementitious waste forms."

The radiation levels typically found at nuclear waste dumps don't seem to pose a problem for bacteria either.

"It doesn't kill them," says Lloyd. "If anything, it actually stimulates the microbes."

The study found that the way bacteria process waste products means hazardous material is less likely to seep into the environment. Some nuclear waste contains cellulose, which can break down to form isosaccharinic acid (ISA) under alkaline conditions. ISA can form a soluble complex with uranium, helping it to leak out of the waste repository. But bacteria seem to use ISA as a carbon source and degrade it, keeping radionuclides in solid form – which means they stay in place.

Microbes may also help prevent radioactive gases escaping. Hydrogen produced by reactions in the repositories could build up pressure and cause them to crack open or explode. But microbes can use hydrogen and keep the levels down. They can also grow in fractures in the rock, form biofilms and clog up pores.

"At the moment, they have safety case models that are built on chemistry and physical containment. If you start including the biology, it means that those models are actually overly conservative, which is a good thing," says Lloyd. ■

Fraudsters list fake firms on Google Maps

LOCAL businesses on Google Maps aren't always as local as they seem. Tens of thousands of bogus listings are added to the maps every month, directing browsing traffic towards fraudulent schemes, finds a team of researchers at Google and the University of San Diego, California.

As an example, a fraudster might list a locksmith at a location on Google Maps. When a potential customer calls the phone number listed, they are put through to a call centre that hires unaccredited contractors to do jobs. Often the customer ends up being coerced into paying more than the quoted price.

To analyse the scope of this abuse, the team looked at over 100,000 listings that were identified as fake between June 2014 and September 2015. The fraudulent listings most often belonged to services like locksmiths, plumbers and electricians.

Overall, less than one per cent of Google Maps listings were fraudulent, but pockets of fake listings emerged. In West Harrison, New York, for example, more than 80 per cent of locksmiths listed were scams. The team presented their findings at the World Wide Web Conference in Perth, Australia, last week.

Google tries to minimise abuse of its maps by sending out postcards to the locations people claim online. Firms have to enter a unique code on the postcard before they can manage their listing.

However, the team discovered a loophole. Fraudsters could rent a post office box in the area to register their business and pick up the card, then change their address within the same zip code – which Google Maps allows without further verification.

"Clearly there is a balance to be struck between making it easy enough for legitimate businesses to use Google Maps, versus making it difficult for illegitimate businesses to exploit it," says Michael Levi at Cardiff University, UK. Timothy Revell ■

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NewScientist

Robot vision test raises its sights

COMPUTER vision is ready for its next big test: seeing in 3D. The ImageNet Challenge, which has boosted the development of image-recognition algorithms, will be replaced by a new contest next year that aims to help robots see the world in all its depth.

Since 2010, image recognition algorithms have been trained on the ImageNet database, a go-to set of more than 14 million images hand-labelled with information about the objects they depict. The algorithms learn to classify the objects into different categories, such as house, steak or Alsatian. Almost all computer vision systems are trained like this before being fine-tuned on more specific images for different tasks.

Every year, participants in the ImageNet Large Scale Visual Recognition Challenge try to code algorithms that can categorise these images with as few errors as possible. Seven years ago, this proved difficult, but now computer vision is great at identifying objects in images.

In 2015, a team from Microsoft built a system that was over 95 per cent accurate, surpassing average human performance for the first time in the competition's history. And photo apps from Google and Apple allow people to search their image collections using terms like "food" or "baby". Google Photos even classifies images by abstract concepts like "happiness".

"When we were starting the project, these were not things that industry had done yet," says Alex Berg at the University of North Carolina at Chapel Hill, who is one of the competition's organisers. "Now they are products that millions of people are using."

So the ImageNet team says it is time for a fresh challenge in 2018. Although the details of this contest have yet to be decided, it will tackle a problem computer vision has yet to master: how to make systems that can classify objects in the real world, not just in 2D images, and describe them using natural language.

"There is very little work on putting a 3D scene through a machine-learning algorithm," says Victor Prisacariu at the University of Oxford.

Building a large database of images complete with 3D information would allow robots to be trained to recognise the objects around them and map out routes. This database would largely comprise images of scenes inside homes and other buildings. It could consist of digital models that simulate the real world or 360-degree photos that include depth information, says Berg. But first someone must make these images. As this is difficult and costly, the data set is likely to be a lot smaller than the one that was put together for the original challenge.

Robot vision is ready for its ImageNet moment, says Andrew Davison at Imperial College London. Domestic robots will need to know how to deal with objects and manipulate the world around them, he says.

Berg isn't expecting major progress in the first couple of years of the new challenge. Eventually, he would like to see robots that can consistently understand their environment and explain what they see just as well as a human can. But achieving either of these things is more than five years away, he says. **Matt Reynolds** ■

OOSTENDE/REX/SHUTTERSTOCK

Looking for context

Virus triggers allergic reaction to gluten

A COMMON, symptomless virus could be responsible for triggering coeliac disease.

This painful autoimmune condition involves the immune system mistakenly attacking gluten – a protein found in wheat, rye and barley – and damaging the gut. Coeliac disease is generally thought to be a genetic disease, but there is some evidence that its onset may be linked to infection with cold-causing adenoviruses or hepatitis C.

Now Bana Jabri at the University of Chicago and her colleagues have obtained the first experimental evidence that a virus can cause the immune system to stop tolerating certain molecules in our food. The group found that exposing mice to a common reovirus called T1L destroys their tolerance of gluten.

When the team fed gliadin – a component of gluten – to mice, the animals produced two to three times as many antibodies against the compound over the next two days if they were also infected with reovirus (*Science*, doi.org/b5cq).

And mice infected with the T1L virus had between two to four times as much of an inflammatory molecule called interferon regulatory factor 1 in their bodies. This molecule is seen at high levels in the gut linings of children with coeliac disease, and has also been implicated in instigating the condition's onset.

"The reovirus changes the way the immune system sees gluten," says Jabri. "Instead of mounting a tolerant, non-aggressive response, the immune system in the presence of the reovirus views gluten as being dangerous, promoting a destructive inflammatory response."

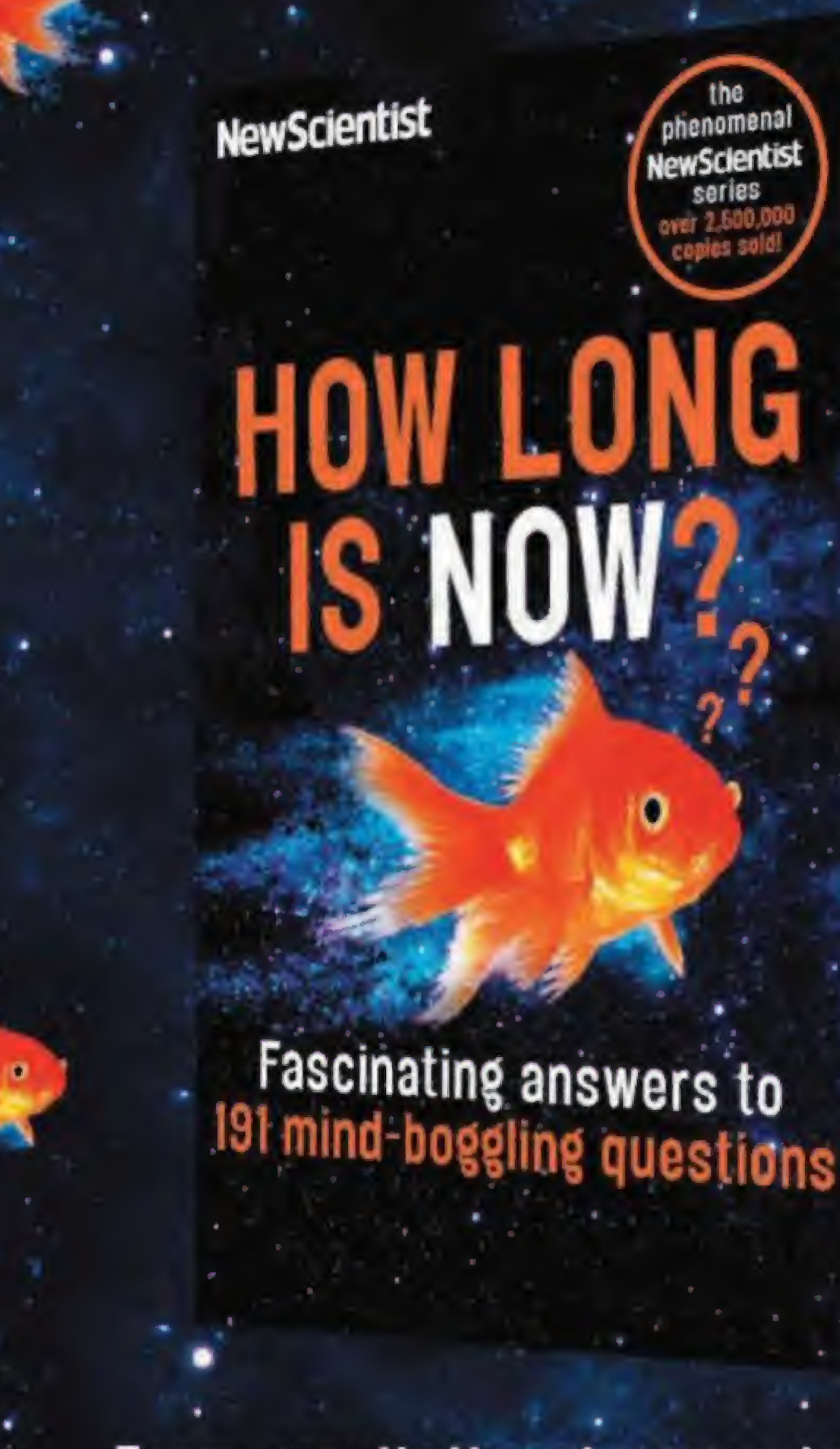
"In the presence of the virus, the immune system views gluten as dangerous, instead of tolerating it"

Gluten is more likely than most other foodstuffs to trigger immunological problems, because it resists being broken down in the gut, says Jabri. Gliadin is the most difficult component of gluten to digest.

"This is a fascinating study," says David Sanders at the University of Sheffield, UK. "Investigators have studied this 'second-hit' hypothesis for some time to explain why not everyone with genetic predisposition actually develops the disease. Now the new study suggests that reoviruses might play a role."

Jabri's team is now working on a vaccine that might stop infections from causing coeliac disease. Andy Coghlan ■

WHY ARE DOGS' NOSES WET?



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NewScientist

DAVID PENNING, MISSOURI SOUTHERN STATE UNIVERSITY

Kingsnakes apply pressure to overpower bigger snakes

KINGSNAKES kill and consume other constrictor snakes 20 per cent larger than themselves. What allows them to pull off the feat has remained a mystery – until now. It's all to do with how tightly they can squeeze their prey.

David Penning at Missouri Southern State University and Brad Moon at the University of Louisiana examined 36 preserved specimens of three species of kingsnake and three species of another type of constrictor, the rat snake. The pair looked at how much muscle the snakes have relative to their body size. They also measured how much pulling force snakes could exert while trying to escape by restraining 98 live snakes in harnesses.

The kingsnakes didn't have a greater proportion of muscle for their size, nor did they exert a proportionally greater pulling force than the rat snakes. But when the team shook dead mice to stimulate live prey, the snakes revealed their secret. Once the snakes wrapped their coils around the mice, the kingsnakes squeezed with greater pressures than the rat snakes – sometimes twice as much (*Journal of Experimental Biology*, doi.org/b485).

The way they positioned the coils as they put the squeeze on their prey seemed to be key to creating their power. "Almost all the rat snakes had this really variable, haphazard application of their body, whereas all the kingsnakes were in this elegant, spring-like pattern," says Penning.

Old drug, new hope for deadliest cancer

A DRUG used to treat strokes significantly prolongs the lives of mice with pancreatic cancer.

In humans, pancreatic cancer has the worst survival rate of any major cancer. Chemotherapy is difficult because the tumours are protected by the stroma – an armour of connective tissue, blood vessels and immune cells.

Now, Paul Timpson and Marina Pajic at the Garvan Institute of Medical Research in Sydney, Australia, and their team have shown that the stroke drug fasudil can weaken this stroma, making it easier for other drugs to get in.

Three days of fasudil treatment prior to chemotherapy increased survival time of mice with pancreatic cancer by 47 per cent (*Science Translational Medicine*, DOI: 10.1126/scitranslmed.aai8504). If this benefit translates to people, it would increase average survival from nine to 13 months. "It doesn't sound like much, but the baseline success for pancreatic cancer treatments is so low that any improvement is fantastic," says Timpson.

Fasudil was approved in Japan in 1995 and is no longer covered by a patent, meaning it is cheap.

The team is now looking at trialling the drug in combination with chemotherapy in people with pancreatic cancer, says Pajic.

A twist could bring moving holograms

A METHOD for mass-assembling semiconductors into fusilli pasta shapes could one day lead to moving holograms projected right from your smartphone.

To create a hologram, information about an object is recorded into a light-sensitive material. A moving hologram requires the light to twist and change so it acts like a flip book.

Nicholas Kotov at the University of Michigan and his colleagues made twisted semiconductors by coating them with amino acids, which are responsible for proteins' twists. The resulting compound acts as a waveguide: light passing through it naturally follows the curves in the material (*Science Advances*, doi.org/f9sx9p).

The goal is to add the structures into technology like smartphones. Kotov says this is the first step. "It is something that we envisioned, but it's not yet a reality," he says.

Soft robotic ray is a stealthy ocean spy

IT'S a drone of the deep. A soft-bodied robot that swims like a manta ray has been engineered to spy on underwater creatures.

The mostly transparent robot has no motor. Instead, it uses artificial fin muscles from a flexible polymer called dielectric elastomer. A silicone-encased battery supplies a cyclic voltage that squeezes and releases the polymer, causing the muscles to bend. This flaps the ray's fins so that it moves through the water.

The robot can swim at speeds up to 6 centimetres per second and can tolerate temperatures between 0.4°C and 74°C (*Science Advances*, doi.org/b5bp). It could be used to explore wrecks or survey coral reefs, says its creator Tiefeng Li at Zhejiang University in China.

Bully Jupiter made Mars so small

MARS can blame Jupiter for its diminutive stature. The Red Planet may be much smaller than it should have been because Jupiter's gravity beat it up as it was forming.

Models of our solar system's formation suggest that Mars should be between 1.5 times and twice the mass of Earth. Instead, it weighs in at a mere one-tenth Earth's mass.

Now an old theory that might explain it has been resurrected: gas left over from the formation of Jupiter meddled with the rocks that formed Mars, making them fall apart rather than clump together.

The gas giants were formed by accreting gas from the protoplanetary disc that surrounded the sun. The disc's gravity pulled the protoplanets' axes of rotation in one direction, but Jupiter's gravity pulled them in the opposite direction. When those forces balanced in a certain way, the protoplanets felt a kick from Jupiter at the same point in their orbit around the sun.

"Before the kicks, collisions between solids occur at low velocity, so they merge," says Scott Kenyon at the Harvard-Smithsonian Center for Astrophysics. "After the kicks, the collisions are at high velocity, so colliding objects fragment" (arxiv.org/abs/1703.10618).

The theory might also hold for other solar systems.

NASA

Elusive volcanic island bird revealed to be the largest canary

ONE of the world's least-observed birds turns out to be the largest canary ever found. A grosbeak, the bird lives in inaccessible forest on the small volcanic island of São Tomé, off the west coast of Africa.

It's an odd-looking bird with burnished brown feathers and a grey, parrot-like beak, that lives in the canopy and makes forays into the world below for a fruit snack.

Francisco Newton, a Portuguese naturalist, collected the first three specimens in 1888. The grosbeak then vanished from popular record until a century later, when a couple of birdwatchers chanced upon it. Its size, strange flattened head and large beak caused confusion among ornithologists. As a result, it was placed in a separate genus, *Neospiza*, which simply means "new finch".

But the São Tomé grosbeak was misidentified. It is actually the largest canary on the planet, 50 per cent heavier than the next-biggest species – though still only the size of a starling (*Ibis*, doi.org/b488).

Martim Melo at the University of Porto, Portugal, collected four new specimens over many years of fieldwork. Genetic analysis shows that it is a canary (genus *Crithagra*). Its closest relative is a seedeater, *C. rufobrunnea*, found on São Tomé and neighbouring Príncipe.

The two *Crithagra* species diverged from a common ancestor about 1 million years ago. "The grosbeak was probably already slightly larger, and selection favoured the increase in bill size, allowing it to explore resources that are inaccessible to the smaller birds," says Melo.

Tool unmasks online puppeteers

THEY spread fake news and dominate forums, sabotaging online discussion. But a new tool can spot "sock puppets": multiple accounts run by a single user.

A study of nine websites that use comment service Disqus to let readers post found that sock puppets can be identified by their writing style and posting activity.

Srijan Kumar at the University of Maryland and his colleagues analysed commenter accounts on US sites including those for CNN and Fox News. They found that sock puppets typically add poorer quality content, writing shorter posts that other users often report or downvote. They post on more controversial topics and are more abusive. Worryingly, their posts are also more likely to be read and to generate a lot of activity.

Based on their findings, the researchers created a machine-learning tool that can correctly identify 91 per cent of the time if two accounts have one owner. Another tool can distinguish between a regular account and a sock puppet with 68 per cent accuracy. The research was presented at the International World Wide Web Conference in Perth, Australia, last week.

DANIEL ESKRIDGE/STOCKTREK IMAGES

Sabre-toothed tigers had bad backs

IT'S not easy being a predator. The sabre-toothed tigers and dire wolves that roamed the area that is now Los Angeles 12,000 years ago often had fractures. The nature of their injuries reflected the way they hunted.

A study of thousands of skeletons of extinct species by Caitlin Brown and Mairin Balisi of the University of California, Los Angeles, found injuries on 4.3 per cent of the tiger bones and 2.8 per cent of wolf bones. Tiger injuries largely affected their shoulders and back, while the wolves generally fractured ankles, wrists and upper necks (*Nature Ecology & Evolution*, DOI: 10.1038/s41559-017-0131).

The tigers probably sustained back injuries while ambushing prey such as bison and camels, and wrestling them into submission. By contrast, dire wolves hunted in packs, running down their prey.

"They have to do everything with their mouths," says Blaire Van Valkenburgh, the team leader. "So we expected to see injuries where they were kicked in the head, and maybe injuries in the limbs, either by being kicked or by tripping while in hot pursuit."

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Carving up continents

Colossal engineering projects could link oceans and seas in ways we hardly thought possible – but at what cost, asks **Fred Pearce**

PLAINPICTURE/SABINE VIELMO

AFTER years of protest, the world's biggest civil engineering project yet is now cleared for takeoff. Late last month, the Supreme Court in Nicaragua turned down the last environmental claim delaying the construction of the $50 billion Interoceanic Grand Canal.

It will carve a 273-kilometre channel through the small Central American country to connect the Atlantic with the Pacific Ocean – even though the Panama Canal, 1000 kilometres to the south, already does the job, and received a massive upgrade less than a year ago.

Why the duplication? Proponents of the canal say it will ease congestion that the upgrade can't address, and create new economic opportunities for Nicaragua. By shortening journeys, it could even help stem the rise in the shipping industry's share of global carbon emissions, which could reach 17 per cent by mid-century.

But the project also raises troubling questions about the environmental chaos that could ensue when alien species navigate between newly linked oceans. This matters even more given that Nicaragua's mega-canal isn't the only one in the works. On the other side of the world, backers of two others have been watching progress closely. One of them will make the Nicaragua project look downright petite.

The natural world can't keep pace with our escalating demand for far-flung goods. An increasing proportion of the world's freight in everything from cotton and crude oil to computers and Christmas toys edges through just two artificial waterways: the Panama Canal and, across the world, the Suez Canal, which connects the Mediterranean with the Red Sea.

"Gargantuan ships carrying over 20,000 containers are quickly making canal upgrades look out of date"

But canals are choke points that are vulnerable to disruption by any number of causes, including administrative screw-ups, natural disasters and the age-old threat of piracy.

It is getting harder to keep maritime traffic flowing smoothly, despite our best efforts. Last June, the Panama Canal saw a $5 billion overhaul completed; in 2015, the Suez Canal was augmented by a second shipping lane cut through Egypt's Sinai desert, at a cost of $8 billion.

And yet such infrastructure upgrades may not be enough. Gargantuan new ships that can carry over 20,000 containers have quickly made them look out of date. In January, the Panama Canal had to reduce the number of parking berths for super vessels, warning of "unusual delays".

Little wonder the Nicaragua canal was an easy sell for some.

In 2013, President Daniel Ortega signed a deal with Chinese investor Wang Jing and his company, HKND Group, licensing them to build a canal across the country and giving them a 50-year concession on its operation. Wang's canal, three times as long and twice as wide as the Panama Canal, would provide a new option for ships plying between China and the US east coast.

Unsurprisingly protests ensued, delaying construction. The project has enraged Nicaraguan ecologists. Its most outspoken critic is Jorge Huete-Perez at the University of Central America in Managua, a former president of the country's Academy of Sciences. Huete-Perez told *New Scientist* the canal would cut through biosphere reserves and destroy 4000 square kilometres of rainforests and wetlands. He also warned it would decimate coastal coral, mangroves and beaches where sea turtles lay their eggs – as well as inundating the villages of several indigenous forest tribes. "The canal project represents the worst nightmare for Nicaraguan conservationists," he says.

Fears are perhaps greatest for Lake Nicaragua. Spanning almost half the width of the country, it is the nation's chief source of fresh water. More than 100 kilometres of it lies on the canal's route, requiring a trench three times the lake's existing depth to be built. That will "irreversibly alter the aquatic environment of Nicaragua," says Axel Meyer of the University of Konstanz in Germany.

Good for the rainforest?

Not every scientist is against the idea. Freshwater biologist Jeffrey McCrary, who is based in Nicaragua, says peasant farmers have already destroyed most of the country's pristine rainforest. Rather than removing what remains, the canal could trigger

Shortcuts for ships

The Panama and Suez canals, both recently upgraded, transformed maritime trade in their day. Three proposed megacanals may do the same

Venice it ain't

economic activity that would give them alternative jobs. HKND's chief project adviser Bill Wild, a construction industry veteran, agrees. "Personally, I believe that the canal is the only thing that will save the Nicaraguan environment."

The project has had a positive environmental assessment, produced for HKND by a UK consultancy. But last November, Nicaragua's Academy of Sciences dismissed it as "propagandistic" and having "no scientific foundation".

Nonetheless, environmental objections have now been sidelined. Ortega, newly re-elected and keen to get going, has increased his attacks on opponents of the canal, snuffing out protests. Construction could start before the end of the year.

While the Nicaraguan canal promises to vastly expand the Central American shipping corridor, a further two mega-canals are being negotiated. They would offer alternatives to two other major sea routes, namely the Bosporus – Russia's sole southerly maritime access to the outside world – and the narrow Straits of Malacca, the gateway to China. Their advocates have watched the Nicaragua protests with interest, and their mood may well have been lifted by developments there.

Bypassing the Straits of Malacca would mean cutting a 50-kilometre notch through a finger of land called the Kra isthmus, in the south of Thailand (see map, left). This would give China, the region's superpower, the option for its ships to avoid the congested straits, shortening a route used at present by a third of all international cargo shipping. Container ships sailing between Shanghai and Mumbai, for example, would be able to shave more than two days off an 11-day journey.

The environmental impact of the project has not been studied but could be considerable, says Ruth Banomyong of the Thammasat University in Bangkok. However, as in Nicaragua, political will is unlikely to bow to environmental concerns. With an estimated cost of $20 billion, the Thai canal will be the cheapest of the proposed mega-canals, as well as the simplest to build. Another plus is that it would fulfil a promise made in 2013 by Chinese premier Xi Jinping to create a "maritime silk road".

"The canal project represents the worst nightmare for Nicaraguan conservationists"

Both the Thai and Nicaraguan canals are dwarfed by a project being plotted to connect the Caspian Sea with the Persian Gulf. Its route would cleave right across Iran, stretching some 1400 kilometres. But length is hardly the biggest challenge. It would also need to traverse mountains up to 1600 metres high, requiring more than 50 giant locks, says Peyman Moazzen, a marine engineer based in Singapore, who has studied the scheme.

But the geopolitical prize might be worth the effort. Such a link would give Russia a long-desired sea route to east Asia that avoids the circuitous journey via essentially Western-controlled seaways like the Bosporus and the Suez Canal. Any environmental concerns would probably be trumped by the fact that Iranians think one of the proposed routes could double as an irrigation canal, watering the desert sands of eastern Iran.

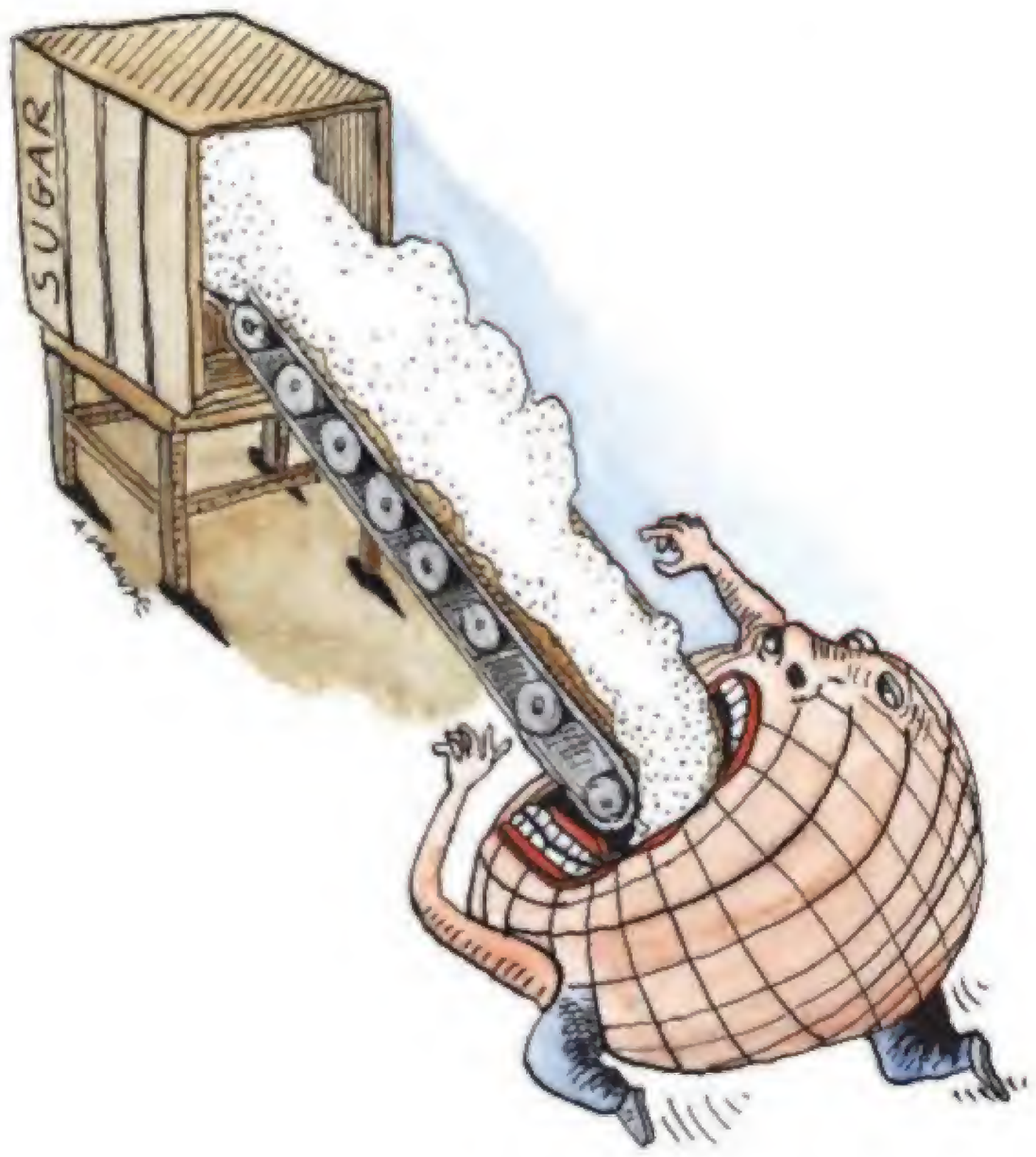
The fates of both the Thai and the Iranian canals may well be determined by what happens in Nicaragua. A major protest will take place in Managua on 22 April, but legal avenues have been shut. The only remaining barriers are raising the money and any faltering in political will.

There may be one last, slim hope for opponents of the canals: an altogether different way for ships to get between oceans. Engineers in South Korea say it might be easier, and more environmentally friendly, to span the relatively flat Kra isthmus with a railway sturdy enough to carry ships weighing up to 100,000 tonnes (not much smaller than the Panama Canal now takes). The Korea Railroad Research Institute, which has pioneered the idea of these so-called "dry canals", suggested earlier last year that it could be built for a quarter of the cost of the Thai canal. A similar project has been proposed in Honduras, just north of Nicaragua.

Is this the start of a new spate of monumental projects that archaeologists will be studying 10,000 years from now? It all depends on how fast we want our stuff. ■

Hard to swallow?

Reducing sugar by a fifth in cakes and cereals sounds easy. So why is big food beefing about it, wonders **Anthony Warner**



"BIG food", that part of industry behind a large slice of what we eat, doesn't usually get a sympathetic hearing. So its recent rumblings about the difficulty of meeting UK sugar reduction targets are likely to have been dismissed by many.

But there is more than a crumb of truth to those rumblings.

The targets, part of a strategy to combat childhood obesity, seek 20 per cent less sugar in nine food types, including cereals, sweets and spreads. It may sound simple, but the devil is in the detail.

For a few categories, cuts are fairly straightforward. In sauces sugar can be removed, and lost volume made up with water. If necessary, low-calorie sweeteners can compensate for flavour changes. But in other categories there are surprising challenges.

Take cakes – for which sugar is more than a sweetener. It is hygroscopic, so retains water, helping keep sponges moist. It also boosts shelf life and quality.

During baking, sugar ups the temperature at which the mix sets, allowing for more aerated, delicate structures to form. It is also responsible for flavours beyond basic sweetness, like caramelised crusts.

Even if you can compensate for such roles, removing sugar can actually increase calories. Sugar contains around 4 kilocalories per gram, so if you just take it out, the proportion of fat (9 kcal per gram) will go up along with total calories if portion size is kept the same.

You could replace sugar with a starch or protein with a similar energy density that won't have this effect. This might look like a good way of meeting targets, but from a calorie point of view, will it do much about obesity?

Low-calorie sweeteners, flavourings and colourings can

An existential threat

Academic freedom remains at stake as Turkey gets ready to vote, says **Caghan Kizil**

AS TURKEY prepares to vote in a constitutional referendum that could hand more power to its president, spare a thought for its scientists and other academics.

Some are still being made scapegoats in a clampdown on critics that began after last July's attempted coup. Another 330 were thrown out of their jobs just weeks ago. Their crime? Signing a petition for peace in a country where growing authoritarianism and the renewal of conflict with minority groups are a worry.

They include an 82-year-old professor, Öget Öktem Tanör, who set up the country's first neuropsychology clinic.

Since last July, the Turkish government has purged more than 140,000 public employees, including nearly 5000 academics. It tries hard to portray these people as having links to the Gülen movement it says was behind the coup, and to terrorists. On the contrary, those ousted most recently include many from Academics for Peace (AfP), who strongly oppose violence.

The truth is last summer's events are being used to try to silence progressive academics who may be critical of the authorities. Those from the AfP, as well as many others, who have been removed are struggling. They have lost jobs, pensions and the right to travel abroad. Some have started academies outside universities to continue teaching students. However, with no financial and logistical assistance these may not last.

"Turkey is being dragged towards a darker place, in which academic freedom faces an existential threat"

In the referendum on 16 April, a "yes" vote would hand more executive power to President Recep Erdogan, who has vowed that one of his first acts if he wins will be to reinstate the death penalty. A "no" would keep hopes for a more democratic future

ease some of these challenges. But there are caveats. Many of the most effective sweeteners, such as aspartame, are not suitable for baking because they break down at high temperatures. Some non-sugar carbohydrates known as polyols can be used as sweeteners. But in sufficient quantities these have a laxative effect that must be made clear on packaging. Not an ideal marketing strategy.

Various dietary fibres can replace sugar's bulk, but these too can cause gastrointestinal upset. What's more, consumers are increasingly suspicious of unfamiliar ingredients.

Behind the sugar targets, there is a sensible commitment that calories should also be reduced, but in many categories of food it may prove challenging to achieve the two together.

Big food is genuinely engaged with this programme, but for it to be successful, everyone needs to be on board. For big companies, with strong R&D capabilities, it may be possible to overcome some of the obstacles. But smaller players in the most challenging categories might rightly feel like they are being set up for failure. ■

Anthony Warner is a chef, blogger and part of The Nourishment Network, a nutrition communication project

alive. Turkey is on a perilous path.

The government and president have campaigned hard for a yes, sending representatives to European Union nations to drum up support from Turks living abroad, causing friction with leaders in countries including Germany and the Netherlands.

Make no mistake, Turkey is being dragged towards a darker place, in which academic freedom faces an existential threat. ■

Caghan Kizil is an associate professor of neuroscience at Technische Universität Dresden, Germany, and a member of the Research Institute on Turkey in New York

INSIGHT Sexual orientation

DR G. MOSCOSO/SCIENCE PHOTO LIBRARY

Biology is not necessarily destiny

A sexuality hormone? It's not that simple

Andy Coghlan

"PRENATAL exposure to progesterone affects sexual orientation in humans". A bold and unequivocal-sounding title for a scientific paper. And certainly important if true. But is it?

The study claimed to show that women given extra progesterone during pregnancy, routinely prescribed to prevent miscarriage, bleeding or premature delivery, have children who are "29 per cent more likely" to later identify as bisexual.

It would be a landmark finding, allowing us to also ground in biology the established social science contention that sexuality has more dimensions than straight and gay.

We suspected that exposing a fetus to strong hormones can shape sexual orientation. But there are no animal models of sexual orientation, and doing this kind of experiment in humans would be deeply unethical. The next best thing would be a retrospective analysis looking at a birth cohort exposed to a specific hormone "in the wild". And that's what this study did.

June Reinisch of the Kinsey Institute in Indiana and her colleagues trawled a public database containing records of more than 9000 pregnancies in Denmark between 1959 and 1961. They identified women who were given a progesterone-mimicking hormone by the trade name lutocyclin to prevent miscarriage.

Lutocyclin did seem to have mild effects on sexual orientation: later in life, exposed individuals were five times more likely to self-identify as non-heterosexual, and were more likely to report relationships with the same sex, than unexposed controls.

Two criticisms of the study are familiar: both its size and the effects

"There is a question about what hormone the trade name of the drug really referred to"

on sexuality are small. Just 34 people – 17 men and 17 women – were exposed to the hormone in utero. One of the men identified as homosexual, two as bisexual and two as "don't know". Of the women, two identified as bisexual.

Not that the study is without value. "I think it's a real effect," says Simon LeVay, a neuroscientist who in 1991 claimed a specific brain region was smaller in gay men. "The study seems well done, and supports the idea that the prenatal hormonal environment affects sexual orientation," he says.

Kim Wallen of Emory University in Georgia feels similarly. "This is a very unique sample, and a real strength is that the subjects only received lutocyclin," he says.

However, Levay and Wallen flag a concern: there is a question as to whether, in the 1950s, the trade name lutocyclin referred to progesterone. They wonder if it could have been ethisterone, a testosterone derivative invented in 1939. A methyl grouping enables it to act like progesterone, but it almost certainly retains the ability to act like the masculine hormone, testosterone, which is also implicated in influencing sexuality through exposure in the womb.

Reinisch says she is "certain" it was progesterone, and if she is right, there could be repercussions. If women conclude that progesterone might affect the sexuality of their child, they may avoid a treatment that could rescue an otherwise doomed pregnancy.

While this study adds to the evidence that extra hormones during pregnancy may alter characteristics, until the result is replicated with a hormone that everyone agrees is progesterone, it is by no means the last word on the origins of bisexuality or the effect of progesterone in pregnancy. ■

APERTURE

Green light for hunt

SHALLOW waters glow in the midday sun off northern Norway, where a mass of Atlantic herring have caught the attention of humpback whales (left) and killer whales (right). That large black splotch isn't a sandbank: it's a shoal of millions of fish about to be feasted upon.

This photograph was shot using a drone last year off the island of Kvaløya. It was taken in January, a time of year when Norway sees little sunshine. Indeed, the light is coming from low on the horizon, despite it being midday. "It's before we get the sun back," says wildlife photographer Espen Bergersen. That's what gives the water its vivid colour.

Bergersen says it was -13°C on this day. "We were planning to go out in the boat, but it was freezing cold," he says. "It was lucky I couldn't start my boat, I guess. I decided to go up with my drone and got this photograph."

While operating the drone from a nearby bridge, he noticed whales circling its supports. "I haven't seen them do that before," he says.

The herring populations have migrated northward over the past 10 to 15 years, Bergersen says, leaving behind the fjords of southern Norway and providing a new feeding ground for humpback whales. The whales stop by on their way from Svalbard – an archipelago between the North Pole and mainland Norway – to the Caribbean, where they spend the winter.

Chelsea Whyte

Photographer

Espen Bergersen
naturepl.com

Make like a leaf

Combine photosynthesis with human tech and we can achieve some extraordinary things, finds Anna Azvolinsky

WHEN Peidong Yang first took living organisms and connected them to electrified silicon wires, no one thought any good could come of it. "When I proposed the idea, people didn't believe it would work," says Yang.

The microbes weren't the only ones that got a shock. Yang's experiments at the University of California, Berkley, and those of a few others, are showing that some organisms can not only survive an encounter with raw electrons pumped through the silicon, but live for weeks this way. In the process, they have opened up a new path towards sustainable energy. The hope is that this fusion of biology and electricity can solve one of chemistry's biggest problems: how to take the freely available power of sunlight and convert it into a cheap, green energy source for everyone.

And not just that. By making microbes that pair some of our best light-harvesting technology with nature's way of using the sun's energy – photosynthesis – we might be able to create tiny, green factories that pump out any useful chemicals we desire.

"Nature knows how to do chemistry and humans know how to make electricity," says Thomas Moore, who studies solar energy capture at Arizona State University. "It makes a lot of sense to put the two things together."

Our desire to harness the sun's power has roots going back a long time. Paul King at the

ISTVÁN SZUGYICZKY

"Meshing plants with technology would turbocharge photosynthesis"

National Renewable Energy Laboratory in Colorado likes to highlight the foresight of an Italian chemist named Giacomo Ciamician. Writing in the journal *Science* in 1912, Ciamician wondered whether harnessing the sun's energy the way plants do would be possible. "So far, human civilization has made use almost exclusively of fossil solar energy," he wrote. "Would it not be advantageous to make better use of radiant energy?"

Fast forward a century and you might think we have achieved his vision. The average consumer solar panel made from rigid silicon crystals now converts between 15 and 20 per cent of the sunlight that hits it into electricity. And other types of solar cell that are flexible and cheap are rapidly getting more efficient too. Plants actually look rather forlorn in comparison: the maximum theoretical amount of sunlight they can convert to biomass is 4.5 per cent. In real conditions, most achieve only about 1 per cent.

But that comparison ignores a problem that has solar energy tangled up in the weeds. Sunshine is not a constant. It only beams down on us during the day and even then it often hides behind clouds, making the stream of electricity from photovoltaic cells intermittent. That would be fine if we could easily store the electricity to use when we need it. But although our technology is getting better at matching electricity supply and demand, we still rely heavily on batteries, which are expensive, bulky and degrade a little with every charge cycle.

Plants have evolved a nifty antidote for the sun's disappearances. They store their energy not on the basis of charged particles, but in chemical bonds. In other words, they make fuel.

"Fuels have intrinsically more storage capacity than a battery," says Dan Nocera of Harvard University, one of the pioneers of artificial photosynthesis. "There wouldn't be enough room for nature to store energy as a battery does."

But whipping up artificial systems that do the same thing is onerous. Plants work their biochemical magic by taking in water and using the sun's power to split it into oxygen, electrons and charged hydrogen ions, otherwise known as protons. Then those protons and electrons are combined with carbon dioxide to form sugars (see diagram, page 30). The whole delicate dance is chaperoned by biomolecules with elaborate chemical architectures that are tough to equal.

Delicate dance

It is Nocera who has probably come furthest along the path to replicating this feat. In 2011, he unveiled what is among the best artificial leaf systems. Its design is simple and its components inexpensive. It looks more like a shiny grey postage stamp than a leaf (see overleaf). It's actually a silicon wafer impregnated with catalysts. But it can certainly make like a leaf. Pop it into water in the sunshine and bubbles of oxygen and hydrogen begin to form. That hydrogen is the key. It is a fuel that can be transferred into pressurised storage canisters or fuel cells, which can convert it back to electricity at will.

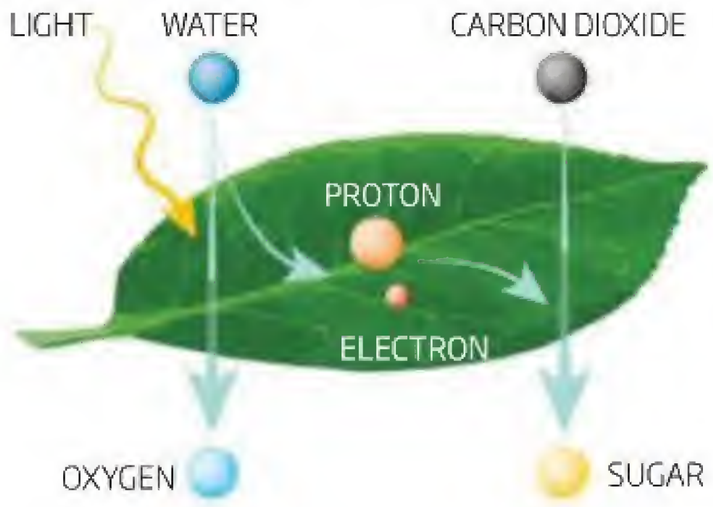
Nocera's efforts are impressive, but they aren't enough to drive an energy revolution. Hydrogen may be a fuel, but dreams of a hydrogen economy have been around for years and progress has stalled. That is partly because the fuel cells needed to convert hydrogen into electricity depend on ›

Green machines

A new generation of sunlight harvesters will be more useful than ever before

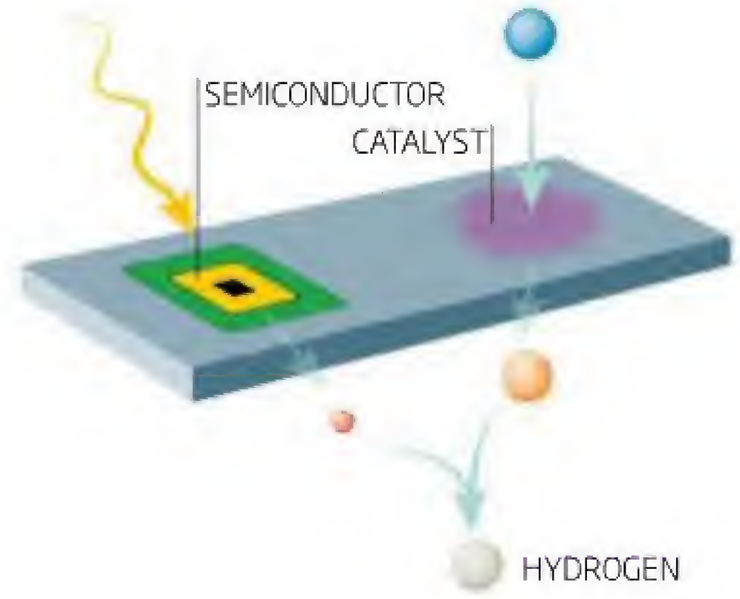
Natural leaf

During the day, plants take in water and carbon dioxide. They use light and a menagerie of enzymes to convert these into oxygen and sugar



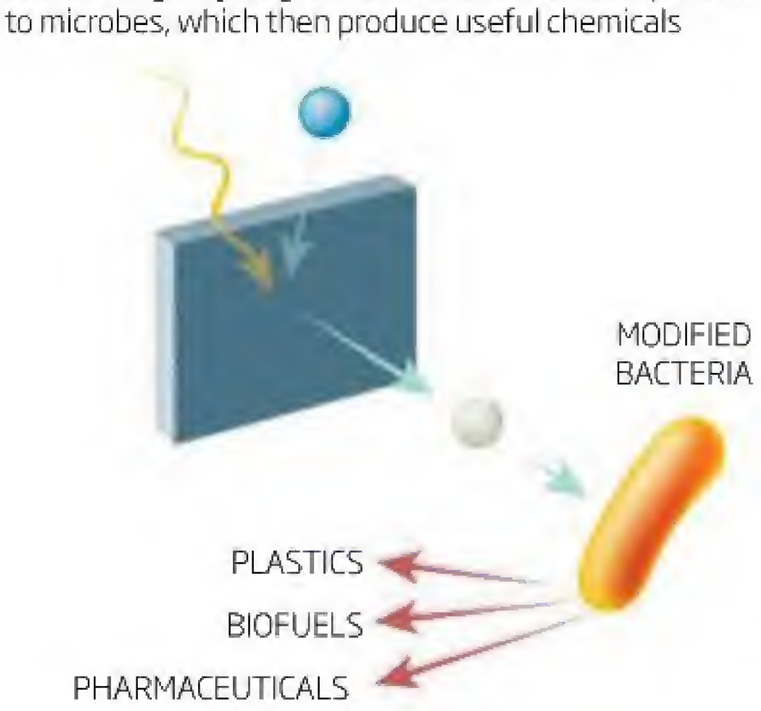
Artificial leaf

Synthetic leaves have a semiconductor to generate electrons from light, and a catalyst to steal protons from water. These are combined to make hydrogen



Bionic leaf

These combine light-harvesting tech with microbes. In one design, hydrogen from an artificial leaf is passed to microbes, which then produce useful chemicals



catalysts made from expensive and scarce metals such as platinum. Plus, society has a massive infrastructure for carbon-based liquid fuels. Hydrogen gas doesn't fit the mould.

Plants don't have this trouble, since they store the energy they harvest as sugar, a fuel that they can metabolise. We would like artificial leaves to do something similar – spit out a fuel that suits our infrastructure. This biofuel would still produce carbon dioxide when burned, but because the artificial leaf sucks it in first, the net emissions would be next to zero.

Yet we have never mastered that final step. "We know how to do solar power to electricity well with photovoltaics," says Moore. "But we don't know how to do solar power to carbon-based fuel."

So a new idea began to emerge. Plants are the masters of orchestrating the biochemistry of fuel synthesis. But human technology surpasses them in terms of generating electrons. Would it be possible to mesh the two together and create a turbocharged cyborg version of photosynthesis?

Nocera was one of the first to investigate. Working with bioengineer Pamela Silver at Harvard, he began by taking the water-splitting, hydrogen-producing synthetic leaf from 2011 and pairing it with a soil bacterium called *Ralstonia eutropha*. The bacteria fed on the hydrogen, blended it with carbon dioxide and spat out a biofuel. Silver's lab tinkered with the bacterium's genome to get it to produce various liquid alcohol fuels.

It worked, but only just. The hydrogen-producing catalyst that Nocera had developed also produced highly reactive oxygen atoms. They were so reactive, in fact, that they disrupted the bacteria's biochemical machinery, killing them off within hours. But in work published last year, Nocera's team revealed a fresh catalyst that could play nice with the microbes. The bionic leaf that resulted was also cheaper than the previous one and wildly efficient. It converted a whopping 10 per cent of the energy in sunlight into fuel (*Science*, vol 352, p 1210).

It was neat, but not in a league of its own. Yang had already begun his experiments with microbes and electricity. And he wanted to go further than Nocera. He wanted to feed microbes not hydrogen, but raw electrons.

"The scientific community didn't recognise that this sort of thing would be possible 10 years ago," says Moore. But we discovered recently that some types of bacteria naturally survive on pure electricity, by directly

ingesting electrons. We also now know that *Geobacter* microbes can take in electrons and use them in chemical reactions. But what Yang wanted to do was something else entirely.

Starting in 2013, his research group showed that certain types of non-photosynthetic bacteria could grow on light-harvesting silicon nanowires. Two years later, the team discovered that the nanowires could transfer electrons directly into the bacteria. The microbes seemed perfectly happy with the arrangement, ingesting the electrons and using carbon dioxide and water to create liquid fuels such as acetate from hydrogen, carbon and oxygen.

Then came what might be a game-changer. Yang and his colleagues took another non-

4.5%

Theoretical maximum efficiency with which plants convert sunlight into chemical energy

Source: *J Appl Phycol*, vol 21, p 509

Daniel Nocera's fully artificial leaf may be sleek, but it can't produce liquid fuel

MYLAN CANNON/THE NEW YORK TIMES/REDUX/EYEVINE

photosynthetic bacteria, *Moorella thermoacetica*, which naturally generates acetate, and added a mix of chemicals, including cadmium ions and the amino acid cysteine. They saw that light-absorbing particles made from cadmium sulphide had appeared on the surface of the bacteria. It seemed that the microbes had made their own solar harvesting jacket from the chemicals (*Science*, vol 351, p 74). "It takes a lot of effort for us to make the semiconductor nanostructures," Yang says. "Here, the bacterial cells created this semiconductor surface themselves." It's a sun-powered fuel factory that replicates itself.

"Yang's work is very exciting – it's completely new," says Erwin Reisner at the University of Cambridge, who is also developing bionic photosynthesis systems.

Questions remain, however, over durability. So far, the electron-consuming bacteria can survive in Yang's apparatus for only several weeks. Yang is still focused on understanding their biochemistry. He hopes doing so will help him improve the efficiency of what he calls his "photosynthetic cyborg system", which is currently 2.5 per cent. "This is all new and we need to understand the details," he says. "Otherwise it is black magic."

And you can forget the sleek silicon wafer style fully artificial leaf; these systems are still prototypes. It's unclear to what extent they can be scaled up. Nocera and Silver are working on a pilot reactor in India, which should provide some answers.

Nocera is at pains not to oversell bionic leaves. "I don't have any false pretences that next year I will solve the global energy problem," he says. The cost of producing fuel from bionic leaves will probably remain higher than extracting oil for the foreseeable future. Nocera says market interventions like carbon pricing will be necessary before devices like his make economic sense. "When we could see this type of technology applied has little to do with discovery and a lot more to do with global markets," he says.

In fact, what's causing the most excitement right now is all the other things a bionic leaf might produce. "It's not just about making fuel," says Moore. "Biology also makes other fantastic chemicals that are valuable for our society."

The first fruits are already being picked. Take ammonia, a molecule made of nitrogen and hydrogen atoms that is a crucial part of fertiliser. We used about 166 million tonnes of it in 2016. Yet we still make it using the energy-intensive and 100-year-old Haber process, which creates lots of carbon dioxide. But a new way of producing ammonia along the same lines as a bionic leaf is on the cards.

King has recently extracted the biochemical machinery that certain types of bacteria use to convert nitrogen in the air to ammonia. Put this into a solution, bubble through nitrogen and add a cadmium sulphide semiconductor and you have a deconstructed artificial leaf with a twist: it now effectively produces ammonia from sunlight. "We've removed the living cell and its complexity and simply worked with an enzyme," says King.

Cyborgs evolve

Purifying the nitrogenase enzyme from bacteria isn't likely to scale up because it's so time consuming. Instead Kings is hoping to show how nitrogenase works and so help synthetic chemists mimic it with easy to handle artificial analogues.

Yang sees a different way forward; not deconstructing cells, but making them more elaborate. At the moment his "leaves" are simple cells, a package of enzymes and biological machinery encapsulated in a membrane. But "evolve" them into more complex cells, with internal units each equipped to do specialised chemical transformations, and you could end up with cells that work as processing lines for complex and interesting chemicals.

"We can start thinking about this as a general renewable chemical synthesis platform," says Nocera. Because the bacteria can be genetically manipulated, it is possible to have them make plastics, pharmaceutical drugs or compounds whose synthesis would otherwise require a lot of fuel. It's this sort of application that Nocera thinks will be the first to be economically viable. "As these processes become cheaper, the next important step would be fuel production."

A neat stamp of approval for such ideas recently came from NASA. Yang has received a funding package from the agency's new Center for the Utilization of Biological Engineering in Space. This outfit plans to use living organisms to produce some essentials for astronauts, including food, fuel and oxygen.

The plan will be to get Yang's bionic leaves to pull off King's trick of taking nitrogen and carbon dioxide and producing ammonia as fertiliser for food crops in space and oxygen to breathe. "On Earth, fuel is it and oxygen is of no value," says Reisner. In space, of course, oxygen is crucial.

Yang is even imagining building a system that combines different types of bionic cells with various functions. These might work more like an organism, with sensing cells checking when oxygen supplies get low, for example, and getting the leaf cells to dial up their photosynthesis.

We have certainly come a long way since Yang first tried connecting his bacteria to electricity. "It's getting closer to the movie *The Martian*," says Nocera. Perhaps one day bionic leaves will eat their electrons on another planet. ■

Anna Azvolinsky is a science journalist based in New York City

20%

Efficiency with which consumer silicon photovoltaic cells convert sunlight into electricity

Source: National Renewable Energy Laboratory

Unholy faith?

The taunt that atheism is just another religion undermines the power of secular thinking. So, is it true, asks **Graham Lawton**

JAN BANNING/PANOS

I RECENTLY discovered that I am a member of a downtrodden minority, one of the most mistrusted and discriminated-against in the world. As a white, heterosexual, able-bodied, cis-gender male, this is not something I'm used to. But my minority status is undeniable. I am an atheist.

I'm not complaining. I live in one of the world's most secular countries and work for a science magazine, so it hasn't got in the way. But for atheists living in societies with a strong religious tradition, discrimination is a real problem. In the US, atheists have one of the lowest approval ratings of any social group. Non-believers are the only significant minority considered unelectable as president – and "unelectable" turns out to be a pretty low bar.

Even when atheists don't face open hostility or discrimination, we often have to endure put-downs about the sincerity of our (lack of) beliefs. One of the most common is that "atheism is just another religion anyway". There is no way to prove or disprove the existence of god, the argument goes, so to deny it is a leap of faith. Ergo, atheism is just like a religion.

"This idea turns up all the time, and it is very loaded," says Lois Lee, who directs the Nonreligion and Secularity Research Network at the University of Kent in Canterbury, UK. "When people say 'atheism is just another religion', they normally mean it in a pejorative way." The subtext is clear: atheists are hypocrites.

But this is more than a personal slight. If atheism really is just another religion, its claim to be a superior way to run the world is fatally weakened. All the criticisms it flings at religion – of being irrational, dogmatic and intolerant – come flying back with interest, and progress towards a more rational and secular society is undermined. So is it true? Is atheism just another religion?

Atheists have been treated with suspicion for centuries. In 1689, philosopher John Locke warned that they are "not at all to be tolerated". The "just another religion" claim seems to have arisen around a decade ago in response to the rise of New Atheism, a scientifically motivated critique of religion led by Richard Dawkins and underpinned by his 2006 book *The God Delusion*. Journalists writing about the movement took to using religious metaphors, calling it "the church of the non-believers" and a "crusade against god". Religious scholars joined the fray to defend their beliefs. Even some scientists

GETTY

Faced with reminders of mortality, both religious people and atheists reaffirm their beliefs

took up the cause. In 2007, evolutionary biologist (and atheist) David Sloan Wilson of Binghamton University in New York controversially described the new atheism as a "stealth religion". His point was that, like many religions, it portrayed itself as the only source of truth and righteousness and its enemies as "bad, bad, bad".

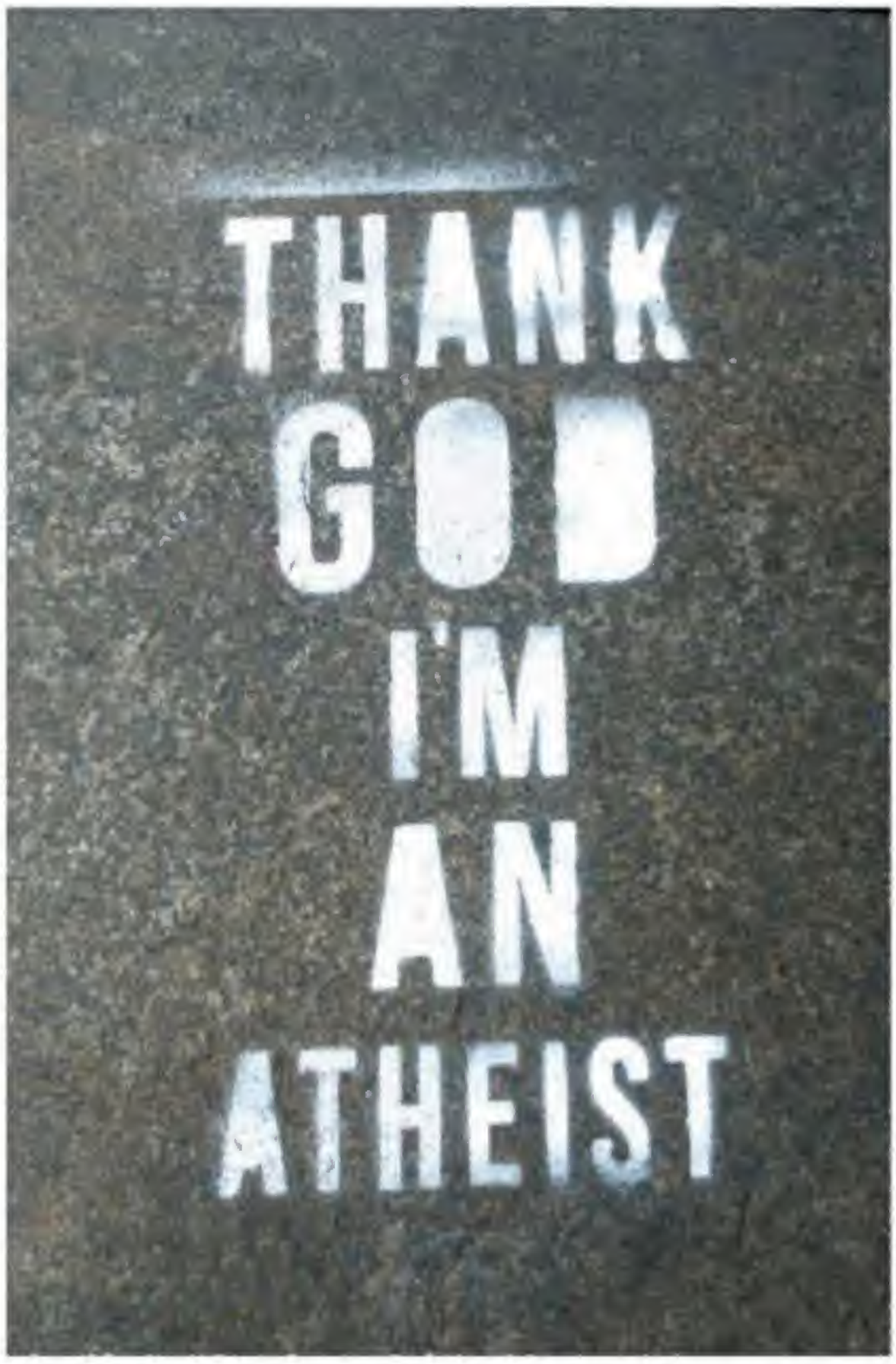
To atheists, such accusations might seem easily refuted. The defining feature of religion is belief in god(s). Atheism defines itself as the absence of belief in god. How can it be a religion? That is like saying that "off" is a TV channel, or not-playing-tennis is a sport.

But atheists arguably have not taken the charge seriously enough. "They'd say, the word just means 'without god'. That is all. We can go home now," says Jon Lanman who works on the scientific study of religion at Queen's University Belfast, UK. Perhaps because of this rather aloof response, atheists have failed to dispel the sense that the critics were on to something.

The truth is that atheism is not simply an absence of belief in god, but also a set of alternative beliefs about the origin and nature of reality. Even though these belief systems diverge in their content and level of fact from religious beliefs, perhaps they originate from the same underlying psychological processes, and fulfil similar psychological needs. Religious ideas, for example, provide stability and reassurance in the face of uncertainty. They help to explain events and provide a moral framework. For these reasons, and others, they are intuitively appealing to human brains. Maybe brains that reject supernatural ideas simply soak up naturalistic ones to take their place. "They may work as replacement beliefs, helping alleviate stress and anxiety as religion does," says Miguel Farias, leader of the brain, belief and behaviour group at Coventry University, UK.

One candidate for a replacement belief that atheists and others might hold is "progress". A few years ago, psychologists in the Netherlands tested this idea. It is well known that religious people often turn to their beliefs to deal with emotional distress. Faced with reminders of mortality, for example, they vigorously reaffirm their faith. This may be why churches are full of death imagery – it is good for business. Does the idea of progress work the same magic for atheists?

To find out, the team got volunteers with a secular world view to either write about their own deaths or about dental pain. Then ›



ED ROONEY/ALAMY STOCK PHOTO

You needn't be religious to believe in a higher power

participants read an essay arguing that progress was an illusion. Those who had been prompted to think about death disagreed more strongly with the essay. The anti-progress essay also made volunteers more aware of their own death, as if it were pulling their comfort blanket out from under their feet. A different essay arguing that progress had been substantial did the opposite.

That's not all. Another primer known to strengthen religious belief is lack of control over external events. Clinging on to god can help people regain at least a subjective sense of control and predictability. And, yes, atheists do it too. Doing the "progress" experiment with people on board an aeroplane, for example, makes them espouse a stronger belief in progress.

For many atheists, scientific ideas have a similar soothing effect. Stressful situations tend to strengthen their belief in science, especially in theories that emphasise orderliness and predictability over randomness and unpredictability. All of which suggests that religious believers and atheists are more psychologically similar than either would like to think.

"It's like saying that 'off' is a TV channel, or not-playing-tennis is a sport"

That could even extend to supernatural thinking. Proponents of the "psychological impossibility of atheism" argue that supernatural beliefs are so hard-wired into our brains that discarding them altogether is not an option. Evolution, they point out, has endowed us with a suite of cognitive tendencies that make belief in non-material beings come easily. As highly social and tribal animals, for example, we need to keep track of the thoughts and intentions of other people, even when they are not physically present. From there, it is a short step to conceiving of non-physical entities such as spirits, gods and dead ancestors who have minds and intentions of their own, know what we are thinking and have some influence over our lives. And, sure enough, there is evidence that even hardcore atheists tend to entertain quasi-religious or spiritual ideas such as there being a higher power or that everything happens for a purpose.

However, even if letting go completely isn't an option, that doesn't mean that atheists are actually religious. "Intuitions about dualism, teleology, and magic are common among non-believers," says Ara Norenzayan, a psychologist at the University of British Columbia in Canada. "But the case is much weaker for belief in God or gods, where cultural learning is much more powerful." And experiments show that people can override their tendencies. "There is no evidence for the argument that all people have an implicit belief in the supernatural," says psychologist Marjaana Lindeman at the University of Helsinki in Finland.

So, despite some similarity between religious and non-religious beliefs systems, they are not equivalent. Surely that buries the claim that atheism is just another religion?

Maybe not. There is another way in which atheist beliefs make them religion-like, according to Sloan Wilson. It is the way they play fast-and-loose with scientific facts. "Atheists will say that religion is bad for humanity, that it's not an evolutionary adaptation – which happens not to be true," he says. "That is how atheism becomes an ideology. It is organised to motivate behaviour. If it uses counterfactual beliefs in order to do it then there's really very little difference between atheism and a religion."

But if using non-factual beliefs to motivate behaviour is enough to make something a religion, then atheism isn't the only offender. Political campaigns are a religion; Father Christmas is a religion; self-help books are a religion. That would seem to lead to such a broad definition of religion that it is almost useless – and certainly doesn't make the accusation against atheism especially damning.

Besides, religion is not just about belief. There are many ways in which atheism is not like a religion, according to Dan Dennett, a

philosopher at Tufts University in Medford, Massachusetts. When somebody puts it to me that atheism is just another religion, he says: "I ask 'in what way?' They usually counter with demonstrably false parallels. We have no rituals, no membership rules, no sacred texts and the small percentage of atheists who belong to specifically atheist organisations are more like people who belong to interest groups like scuba divers or guitar aficionados. And most atheists don't feel the need to proselytise."

What's it all about?

Atheism lacks other features of religion too. "Can atheism provide a strong sense of meaning and purpose?" asks Sloan Wilson. "Can it motivate people to prosocial action, can it get you out of bed in the morning with enthusiasm to do things? I think the answer is theoretically yes... but only for a few individuals."

So there we have it. Atheism is both like a religion and not like one, depending on which aspects you consider. And therein lies the real problem, and the reason why the question of whether or not atheism is just another religion goes around and around in circles. Atheism is not one thing. Nor is religion. "Asking 'is atheism a religion?' is a terrible question," says Lanman. "You can't answer it because both are social constructs." In other words, they are categories that we impose on the world rather than things that exist independently in it.

In that respect they are similar to the category "weeds". Everybody knows what a weed is, but try to produce scientific criteria to distinguish weeds from non-weeds and you will fail. It is impossible, for example, to develop a weedkiller that kills only weeds. "In the scientific ontology that has been built up through biology and botany, there's no place for a category 'weed'," says Lanman. "The things we label weeds have nothing causally to do with one another."

Without a causal connection, you can't do science. You cannot produce a description of a social construct that distinguishes it from other things. You can't discover what causes it, and you can't make predictions about it. You certainly cannot answer the question "is social construct A just another instance of social construct B". You might as well ask "are bushes just another sort of weed?". Er, sometimes. It depends.

And so it is with atheism and religion. "We've been using inadequate concepts," says Lee. "To answer the question, you've got to have a coherent idea of what "religion" is, as well as what "atheism" is." And that's not possible. You can identify beliefs and behaviours that are often part of the social construct we call religion and you can do the same for the social construct we call atheism (see "Elements of atheism", left). But you can't really compare the two, says Lanman. Neither really exists.

That, of course, won't win me an argument in a pub or across the dinner table. But according to Lee, the argument is still worth having. "It may be a daft question, but it gets at a bigger debate about what it means to be religious and what it means to be non-religious. About 50 per cent of Britons are unbelievers of some description, and we really don't know what we mean by that." Amen. ■

Graham Lawton is executive editor of *New Scientist*

The Sunday Assembly aims to be 'something like church but without God'

DAVID LEVENE/EYEVINE

ELEMENTS OF ATHEISM

Religion is not one thing but many. To understand it, you need to break it up into smaller pieces. For example, it often – but not always – features a belief in supernatural agents. And it often – but not always – features a social identity as a member of a group. These are clearly not the same thing, and can be studied in isolation from one another. What are beliefs and where do they come from? What are social identities and how do they form?

By breaking apart religion in this way, scientists find at least five other phenomena. These are: creation beliefs; afterlife beliefs; magical causation beliefs; rituals; and sacred or non-negotiable values. It is tempting to think of these as the "ingredients" of religion, but that is a mistake, says Jon Lanman at Queen's University Belfast, UK. In fact, religion does not really exist. It is a social construct, the name we give to collections of these beliefs and behaviours (see main feature). The more there are, the more likely we are to call it a religion. But none is essential, and one can be enough.

Lanman has applied the same process to the social construct we call atheism. It breaks down into five elements: moral opposition to religion; absence of belief in nonphysical agents; an atheist social identity; rituals; and sacred values. Again, this is not an ingredient list, but captures the various beliefs and behaviours that we typically call "atheism".

One conclusion is that religion and atheism do have things in common, sometimes. Both feature sacred values, which are beliefs that people would not trade for material goods. Both have rituals – although atheist ones are rare – and distinct social identities. But the content of these features are very different. An atheist's sacred value might be that religion should have no place in government, whereas a Muslim's might be the exact opposite.

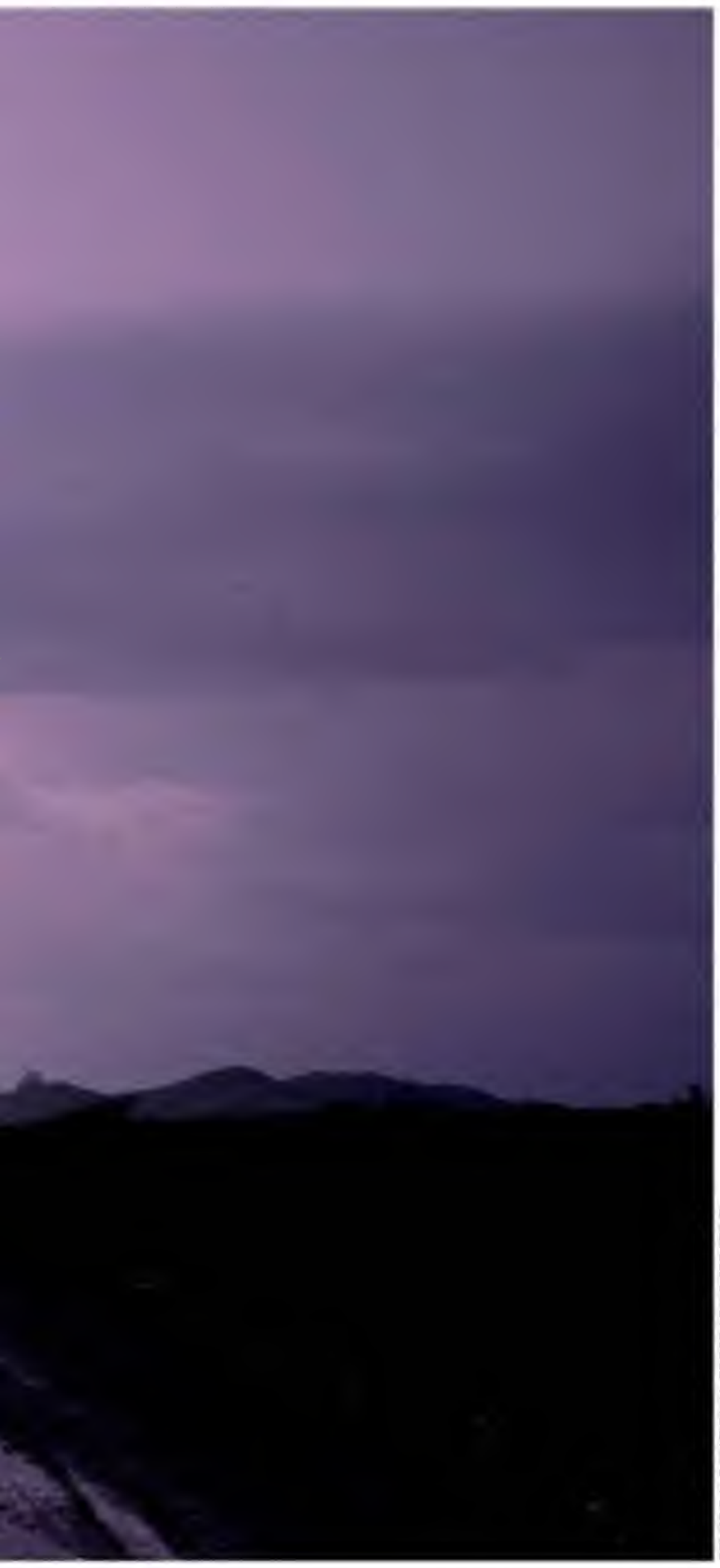
Flash of inspiration

We're starting to illuminate lightning's persistent mysteries, finds **Shannon Hall**

JOSEPH DWYER had never been a big fan of flying. Things took a distinct turn for the worse, though, when his plane accidentally flew into a thunderstorm. "I was certain that we were all about to die," he says.

But it comes with the territory. When Dwyer, a lightning researcher at the University of New Hampshire, began a study that would take him near the edges of thunderclouds in a Gulfstream V jet, he knew it would mean getting up close and personal.

The first two flights were smooth – fun, even. Then he and his colleagues headed up again. "We went inside a cloud and I couldn't see anything any more. Then all hell broke loose," says Dwyer. The plane started to violently rock back and forth, before plummeting several thousand feet.



BRUCE DALE/NATIONAL GEOGRAPHIC CREATIVE

"I completely lost my sense of what was up and down, and so to me it felt like we were barrel-rolling toward the ground."

Luckily, they landed safely. But they had encountered one of the central problems of lightning research – getting a peek into the stormy nurseries where it arises can be not only difficult, but also dangerous. As a result, we still know comparatively little about how lightning forms. This is surprising given that the phenomenon is so widespread – roughly a hundred lightning flashes happen somewhere around the globe every second. Slowly, though, researchers like Dwyer are shedding light on the electrical processes responsible for this spectacle. What they are finding is making us realise we may have had lightning back to front all along.

It's always stormy somewhere: globally, 100 lightning flashes happen every second

Dwyer follows a long line of physicists who have attempted to understand these mysterious bursts of charge. One early pioneer was Benjamin Franklin. In 1752, so the story goes, he attached a metal key to a kite and flew it into a thunderstorm. As he subsequently went to touch it, sparks flew – much like the ones that pop when you shuffle across a shaggy carpet and reach for a metal doorknob. The observation was enough to make him think of lightning as simply a scaled-up version of the same phenomenon.

When you walk across a carpet, the friction between your feet and the floor scrapes negatively charged electrons off the carpet that run up through your body and give you an overall negative charge. This build-up of charge may seem trivial, but over short distances the electric field it generates can grow surprisingly powerful.

As your finger edges towards the neutral doorknob, the electric field increases in strength until free electrons in the air can no longer resist it. If in some region the field reaches the critical value of 3 million volts per metre, known as the breakdown field, the electrons start to accelerate along those powerful field lines. Their motion knocks other electrons loose from nearby atoms, increasing the local field and making more of the air conductive. This creates a bridge that can sustain a current running from your hand to the doorknob, resulting in that noisy, somewhat painful electrical discharge.

Friction is the root of the scaled-up electric field in thunderstorms, too, although its origin is different: hail falling through clusters of ice crystals (see "How lightning forms", page 39). The friction rubs electrons from the crystals, and a positive charge builds towards the top of the cloud where the crystals collect, buffeted by the storm's strong updrafts. The now negatively charged hail, meanwhile, continues falling to the bottom of the cloud. This charge separation creates an electric field between the top and bottom of the cloud, just like the one between you and the doorknob.

But when the field somewhere inside a thundercloud grows strong enough to cause breakdown, the results are rather more spectacular than a spark off a doorknob. Electrons carve ionised channels through the air – each about as wide as a finger – hunting for the nearest positive charge. During a familiar cloud-to-ground lightning flash, the negative charge finds this at Earth's surface. But the most common type of lightning discharge is an intra-cloud flash, where it runs up to the positive region at the top of the cloud. Either way, once one of these so-called lightning leaders reaches a region of opposite charge, electric current explodes between the two points, creating lightning flashes five times hotter than the surface of the sun.

There's just one problem with this picture: although we have been sending balloons and aircraft into lightning-charged thunderstorms since the 1950s, we haven't observed that 3 million volts per metre electric field needed to cause breakdown. Instead, the field is typically 10 times weaker than the ones we generate on deep-pile carpets.

That suggested that lightning operates in a different way to a conventional electric spark. Unlikely as it sounds, perhaps the most promising alternative is that lightning gets a boost from outer space.

Every second, billions of high-energy particles crash into our atmosphere. For the most part, these cosmic rays pass unnoticed, but if they collide with a free

"The most promising idea at present is that lightning comes from outer space"

electron in a thunderstorm, they give it a speed boost. This newly energised electron ionises large numbers of air molecules, triggering an avalanche of high-energy electrons. The resulting sudden accumulation of charge briefly intensifies the electric field, albeit on a tiny scale. Although the details are still murky, the added effect of this localised field may be enough to spark lightning in an effect known as a "runaway breakdown", without the background electric field being anywhere near 3 million volts per metre.

Support for this theory came in 1991, shortly after NASA launched the Compton Gamma Ray Observatory into orbit. Its mission was to search for gamma rays, the most powerful form of radiation in the universe, usually created when stars explode. So it was a surprise when the observatory detected these high-energy photons coming from thunderstorms in Earth's atmosphere as well as from objects beyond the Milky Way.

Physicists were quick to connect the dots. As cosmic-ray-accelerated electrons in our atmosphere gather speed, they not only produce further high-energy electrons, but also a side of high-energy photons. The detection of such gamma rays was therefore ›

SPARK OF RECOGNITION

From flashes of light that resemble sea monsters to electric orbs thought capable of melting glass windows, lightning comes in all sorts of bizarre forms.

SPRITES: Once thought to be a myth, sprites are fleeting flashes of red light high above the clouds that look like giant jellyfish. These are believed to be produced by the strong electric fields generated in the upper atmosphere when lightning hits the ground, but we don't yet understand exactly how they form.

ELVES: These glowing doughnut-shapes of light grow to 400 kilometres across and then disappear – all in less than a millisecond. They are thought to arise when the electric field in a cloud causes electrons to smash into nitrogen molecules, which in turn give off a distinctive red glow.

BLUE JETS: Occasionally glimpsed from the International Space Station, blue jets snake upwards from thunderclouds to a height of roughly 50 kilometres and then vanish one-tenth of a second after they begin. Their comparative rarity has made it difficult to understand their origins.

UPSIDE-DOWN LIGHTNING: When it comes to neutralising the electric field between a thundercloud and the planet's surface, why should the cloud always have to give way? Sometimes lightning forms at ground level and shoots upwards until it hits the cloud. The specifics of when and how it strikes remain a mystery.

BALL LIGHTNING: Orbs alive with electricity have been seen melting glass windows, floating through buildings and even bouncing down the aisles of aircraft. Although people have reported this so-called ball lightning in nature for more than 2000 years, scientists are unsure what is really going on. "There are many theories, but none is fully accepted" says Martin Uman at the University of Florida.

FELICITY LANCHESTER/NATUREPL.COM

It's always stormy somewhere: globally, 100 lightning flashes happen every second

a sign that runaway breakdown was at work.

Yet as tantalising as this link appears to be, it could be a coincidence: we have no direct evidence that this process is what's going on. The trouble is that when it comes to what's happening within thunderstorms, we're more or less flying blind. For a start, lightning is a very localised process, says Steven Cummer at Duke University in Durham, North Carolina. Even in Florida, the lightning capital of the US, lightning strikes a given square kilometre maybe 10 times a year. To boot, lightning's low predictability and high speed makes the birth of bolts hard to spot. "In terms of space, you've got a box that might be a few hundred metres on a side," Cummer says. "In terms of time, you've got maybe one millisecond." Then there's the fact lightning comes in many guises (see "Spark of recognition", below).

Another challenge with identifying the electric fields within thunderstorms is that instruments such as balloons or aircraft used to penetrate storm clouds fundamentally alter the cloud's environment. Balloons, for example, are often struck by lightning, drastically lowering any nearby electric field. This raises questions about much of the electric field data collected in clouds over the past few decades.

So if we want to see what's going on in the roiling black heart of a thunderstorm, we need to find ways of peering in from a distance. Luckily, there is a way. The fluctuating electric fields produced by lightning results in large amounts of radio noise being emitted, causing a crackle similar to that heard on old-fashioned analogue radios. In the mid-1990s, physicist William Rison at New Mexico Tech and his colleagues realised they could use GPS receivers to precisely map that radio noise, and therefore the lightning flashes. Today, Rison's Lightning Mapping Array stretches across 16 stations in the Magdalena mountains of nearby central New Mexico. It can take 3D images of lightning within a thundercloud, but there's one caveat: its time resolution is not so good.

Rison and his team are working on that. Last year, they developed an interferometer to detect the radio waves, fitted with a high-speed camera capable of capturing lightning flashes at more than 180 million frames per second. With this device working alongside the Lightning Mapping Array, the video is accompanied by a full, three-dimensional map providing the most accurate images yet of lightning bolts in action.

When the researchers went into the field to test it out, they hoped to get detailed pictures of runaway breakdown. The results, however, weren't what they expected. Instead, an alternative mechanism seemed to be at play,

"Lightning emits a lot of radio noise, crackling like an old-fashioned receiver"

a mighty spark hidden deep within the clouds that could raise the electric field without the need for extraterrestrial assistance. But rather than beginning in a negative region within the cloud and running to a nearby positive region, as expected, it did the opposite.

"We spent weeks arguing among ourselves," Rison says. "Is this real? Do we understand how our instrument is working? Did we flip a sign somewhere in our measurement?"

Not exactly. What Rison and his team realised was that the perceived flow of positive charge amounted to a rush of electrons going in the opposite direction – much like the apparent accumulation of sand left behind by a receding tide.

The culprit, in their view, might well be a tiny ice crystal somewhere in the cloud with a negative charge on one side and a positive charge on the other. If the positive charge

grows strong enough to tear off electrons in the air in front of it, it can ionise the air and create another positive charge just beyond the crystal. They called this weird observation fast positive breakdown. This ionised patch of air then behaves like the crystal's new tip, a process that repeats itself for as long as the electric field is strong enough to sustain it.

"What you get is this little wiggly ribbon of ionised air that starts growing past the end of the ice crystal," says David Smith, a physicist at the University of California, Santa Cruz. "As that positive 'streamer' grows, it's like a vacuum cleaner sucking up negative charge." And it sends that charge back towards the ice crystal, like a swimmer pushing water behind her. Once the ice crystal accumulates enough added charge, it can spark a lightning leader, the forerunner to a strike.

These streamers have been observed in nature before – but never as a precursor to lightning initiation. And although Rison's team thinks the fast positive breakdown they observed may have been caused by one of these, they can't be sure. Getting a clearer picture of the microscopic physics involved will require tools much more precise than radio wave detectors.

Ningyu Liu, a colleague of Dwyer's at the University of New Hampshire, has been using computer simulations to try to resolve the matter. Already, he has successfully replicated positive streamers emanating from ice crystals, but the 5 centimetres he has so far been able to model don't capture the full picture: in nature, such channels have been observed stretching for 100 metres.

For some researchers in the field, the evidence for fast positive breakdown is a crucial step. "It's kind of like when you're doing a big jigsaw puzzle," says Dwyer. "The interferometer data is that first edge or corner that lets you start the rest."

But that doesn't mean runaway breakdown doesn't happen. The background field strengths measured within thunderclouds perfectly match the lower fields required for runaway breakdown, and many doubt that match is a mere coincidence. Smith thinks these runaway electrons act as a thermostat, generating small discharges that bring the electric field's strength back down again whenever it gets too high. Kenneth Eack at New Mexico Tech agrees. "It's kind of like a slow leak in your tyre," he says. "You can never exceed a certain point because if you do then the leak increases."

But Dwyer thinks it could still play a role in lightning's formation, along with a number of other processes. "The real answer is probably complicated," he says. And as with any recipe, it might require multiple ingredients.

So he will once again focus on those high-energy photons. Although the gamma glows emanating from thunderstorms aren't proof that cosmic rays cause lightning, Dwyer finds it promising that they tend to occur right before lightning begins to form.

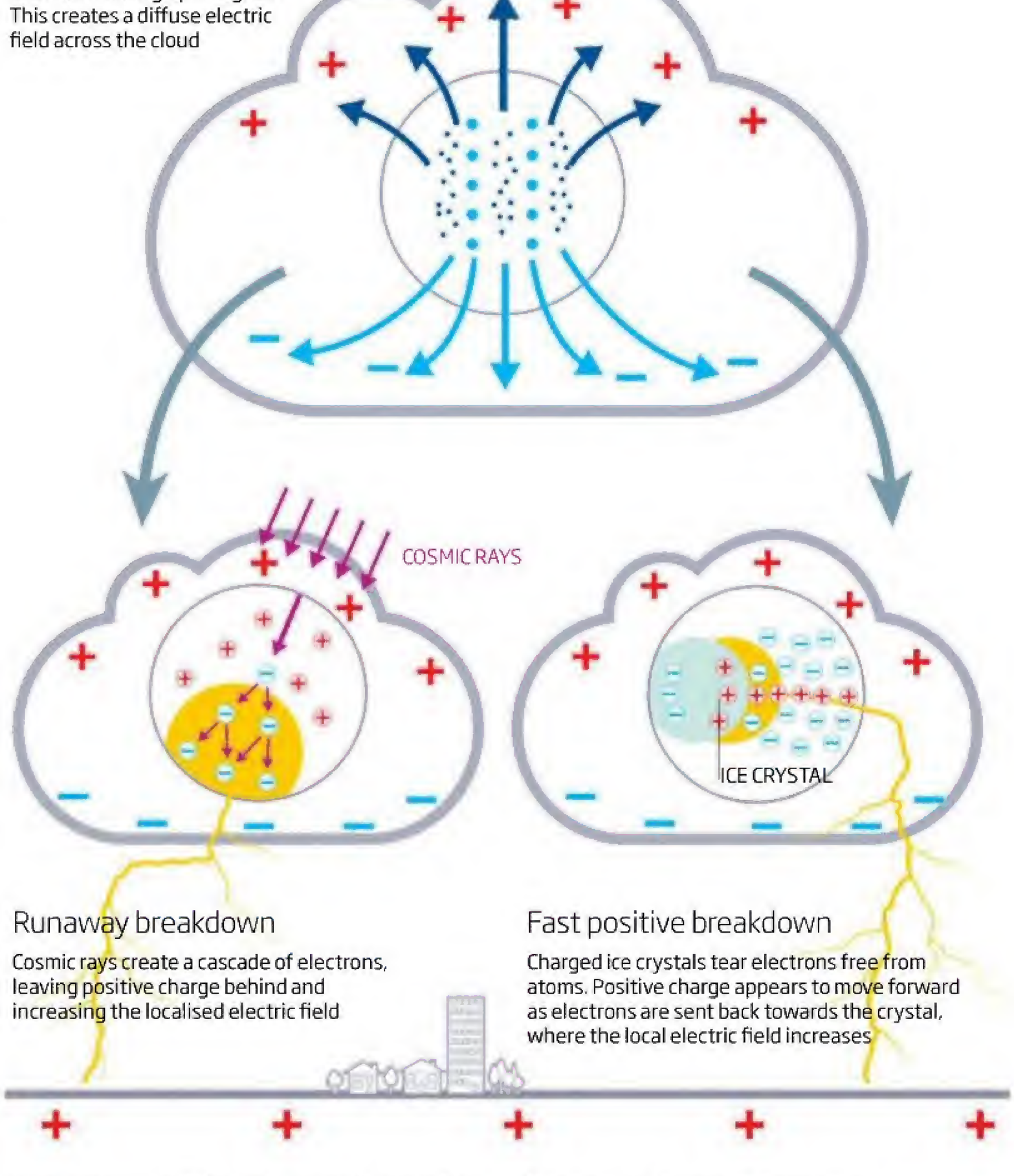
So, each summer for the next three years, Dwyer and Liu will visit Florida, armed with a grant from the National Science Foundation, weather balloons equipped with gamma ray detectors, and powerful cameras.

This upcoming work, together with follow-up observations from Rison's instruments, should bring scientists closer than ever to cracking the mystery. "I think in 10 years, people will be pretty confident they understand how lightning is initiated," says Martin Uman, a physicist at the University of Florida. And if Dwyer is lucky, without ever needing to fly into a thunderstorm again. ■

Shannon Hall is a science writer based in New Hampshire

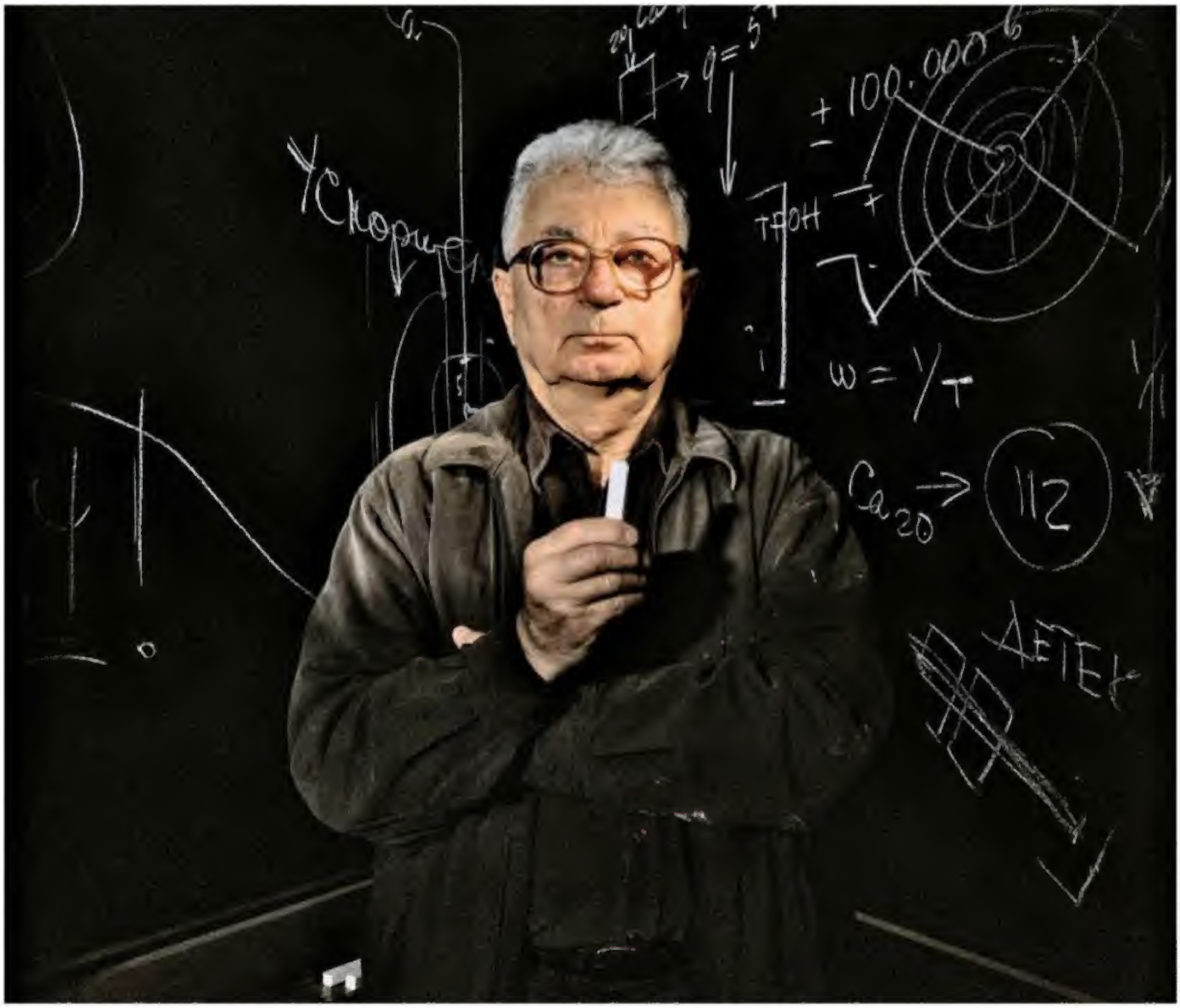
How lightning forms

The electric field generated inside thunderclouds is not big enough to cause lightning on its own, but two other localised processes may be enough to tip it over the edge



Breaking the periodic table

New element 118 could send shock waves through the atomic world, warns Russian nuclear physicist **Yuri Oganessian**, after whom the superheavy atom has been named



MAX AGUILERA-HELLWEG/INSTITUTE

You're the only person alive to have an element named after them. How does it feel to join the likes of Albert Einstein and Marie Curie?
For me, it is an honour. The discovery of element 118 was by scientists at the Joint Institute for Nuclear Research in Russia and at the Lawrence Livermore National Laboratory in the US, and it was my colleagues who proposed the name oganesson. My children and grandchildren have been living in the US for decades, but my daughter wrote to me to say that she did not sleep the night she heard because she was crying. My grandchildren, like all young people, reacted quite calmly.

How many elements have you helped discover since you started working on them in 1956?
We've come a long way. When I started, we had only 101 elements. Today, it's 118, completing the seventh row of the periodic table. Since I joined the Flerov laboratory, I've mostly been making elements, which is why I helped discover many of them. Our collaboration with US researchers has also been strong, even during the cold war.

How do you make superheavy new elements?
With great difficulty. For an atom to exist, it needs a nucleus that balances attractive and repulsive forces, so we need a "magic number" of protons and neutrons. We create new elements by accelerating atoms to a tenth of the speed of light and smashing them into heavier, target elements. When we get a collision, there's a small chance they'll fuse to make a superheavy nucleus. Then there's the challenge of cooling it down and shepherding the element into a detector.

What other challenges do you face?
As atoms get bigger, they need a higher proportion of neutrons to protons, so to create a superheavy element, the atoms you smash together need an excess of neutrons, too. The problem for us is getting the raw materials. We've been using calcium-48, which is very rare and expensive. One gram costs more than $200,000. Making the target material is also slow: our US collaborators produced just 22 milligrams of target material – berkelium, element 97 – after one year of neutron bombardment in a nuclear reactor.

How long do superheavy elements last for?
The longest-lived synthesised isotope of element 112 has a half-life of 29 seconds. For element 114 it's 2.6 seconds, and element 116 is about 60 milliseconds. 118 lasts for around 0.9 milliseconds, so they are getting increasingly unstable. And as superheavy atoms get bigger, they get harder to make. For element 118, we currently produce just one atom per month.

How much higher will the periodic table go?
There has to be a limit, and I think it will come from relativistic effects. When the positive charge of the nucleus increases, the velocity of the electrons increases too, bringing them closer to the speed of light. We are already close. For example, the innermost electrons of element 112 travel at seven-tenths of light speed. Bringing the velocity of the outermost electrons even closer to light speed may change an atom's chemical properties, breaking periodicity.

Oganesson should, in theory, be a noble gas. Do you think it will behave like one?
That will be the first task when we study element 118's chemical properties in earnest. It is very unlikely to be a noble gas, which would mean the end of periodicity as we know it – a very big deal. Our big challenge now is to work out how to handle element 118 when it has a half-life of less than 1 millisecond.

We want to explore the chemical properties of our most recent superheavy elements, and especially their periodicity. To do that, we need to produce more of them. We are involved with a joint proposal to create a new facility. We call it the Superheavy Element Factory. Our US colleagues will improve their reactor to produce more target material, while here in Dubna we will build a new accelerator and new experimental machine. We aim to have a first beam at the new accelerator by the end of this year and to increase production by a factor of 100. These steps may also be key to making elements beyond 118 for the first time.

Why are superheavy elements important?
For me, it is about tackling fundamental questions in atomic physics, but it also bears on astrophysics. Look at a neutron star. It may be 20 kilometres across, yet be the same mass as the sun. They are made of very dense neutron matter: if you cut 2 kilometres into one, you would find material with the same density as an atomic nucleus. It is some sort of soup of neutrons, fewer protons and very heavy neutron-rich nuclei.

What are you looking forward to now?
To see closer to the top of the "island of stability". Theorists predict that there should be some superheavy atoms, with certain combinations of protons and neutrons, that are extremely stable. We have a "continent" of stable elements that ends with lead, element 82. As we go heavier than lead, we have a

"It looks like the end of the material world, but I don't think it is"

"peninsula" created by the likes of thorium and uranium, which are radioactive and so decay over time into lighter elements. Superheavy nuclei are highly charged matter. The repulsion of positively charged protons prevents the formation of large nuclei and this moves us into the deep water of the "sea of instability", where elements break down ever faster. It looks like the end of the material world, but I don't think it is.

The island of stability is a controversial idea. You think it could exist?
If it didn't, we could not synthesise elements heavier than element 112. Their lifetimes are extremely small, but if neutrons are added to the nuclei of these atoms, their lifetime grows. Adding eight neutrons to the heaviest known isotopes of elements 110, 111, 112 and even 113 increases their lifetime by around 100,000 times. This is because we are heading inland on the island of stability and I feel we are now on firm ground, but we are still far from the top of the island where atoms may have lifetimes of perhaps millions of years. We will need new machines to reach it. ■

PROFILE
Yuri Oganessian leads the Flerov Laboratory of Nuclear Reactions at the Joint Institute for Nuclear Research in Dubna, Russia

Interview by Richard Gray

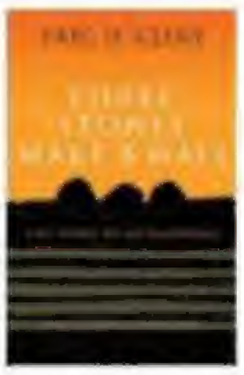
Raiders of the lost phone

Will future archaeologists hilariously misread our culture, wonders **Andrew Robinson**

JAMES L. STANFIELD/NATIONAL GEOGRAPHIC CREATIVE

Former glories: excavating Ebla, one of Syria's oldest sites

Three Stones Make a Wall: The story of archaeology by Eric H. Cline, Princeton University Press



WHAT would an archaeologist digging in the remains of our cities two millennia from now make of our civilisation?

That's a fine question, posed by long-time US archaeologist Eric Cline in the stimulating epilogue to his new book, *Three Stones Make a Wall*. Assuming that our noticeboards and signposts, if not our long-vanished emails and websites, are still decipherable in AD 4000, most large urban structures, such as highways, bridges, schools and even archaeological museums, should be easy enough to figure out.

But what about what Cline labels "the ubiquitous rectangular blobs of metal, plastic, glass and circuitry that seem to be associated with every skeleton", frequently found clutched in a bony hand? Will future diggers know that these were once communication devices?

And what of the still more puzzling shrines or temples "complete with a goddess wearing a crown and with flowing locks", located on virtually every street corner? "I think there is a good chance of misidentifying Starbucks as a religion," jokes Cline. After all, a religious purpose is the typical explanation put forward by today's archaeologists for anything incomprehensible that they find in ancient ruins.

Most of Cline's book deals with the stories of dramatic discoveries since archaeological excavation became methodical, beginning at Herculaneum and Pompeii in the 18th century. These are selected from around the Mediterranean and a few other parts of Europe, the Americas, Egypt and the Middle East, with occasional forays into the rest of Africa and Asia. For reasons that aren't explained, Russia, the Indian subcontinent, Japan, Australia and Polynesia don't feature.

Interwoven with these stories are the careers and colourful personalities of some well-known archaeologists, such as Heinrich Schliemann at Troy and Mycenae, Arthur Evans at Knossos, Howard Carter at Tutankhamun's tomb, Leonard Woolley at Ur, and the Leakey family in east Africa. There are some more recent pioneers too: underwater archaeologist George Bass, the excavator of Bronze Age shipwrecks in the Mediterranean, and David Stuart, Mayan script decipherer and the youngest person to receive a MacArthur Fellowship, at just 18.

"What of the puzzling shrines or temples with a goddess wearing a crown, on every street corner?"

Both the discoveries and the discoverers are illuminated by gritty fieldwork recounted from Cline's experience at sites around the eastern Mediterranean, such as the ancient city of Megiddo in Israel, known as Armageddon to the Greeks. This area was the focus of his valuable 2014 book about the Bronze Age, *1177 BC: The year civilization collapsed*.

The mix is an enjoyable and wide-ranging one. That said, the most original and clearly scientific sections of *Three Stones Make a Wall* are four chapters prompted by the questions non-archaeologists are wont to ask. How do you know where to dig? How do you know how to dig? How old is this and why it is it preserved? Do you get to keep what you find?

Cline patiently explains. Where to dig depends on the surveying methods. These range from people on foot fanatically scouring areas for artefacts, to aircraft scanning jungle terrain using aircraft equipped with laser tech (lidar), to the sophisticated interpretation of satellite images by individual archaeologists.

In 2010, for example, Cline and fellow academic Sarah Parcak purchased some Quickbird satellite imagery of the area around Tel Megiddo. "Almost immediately," writes Cline, "we saw the outlines of what looked like a large building in a field right next the ancient mound." The images had pinpointed the exact spot Israeli archaeologist Yotam Tepper had earlier proposed as the probable location of the camp of the sixth Roman legion during the 2nd century AD.

The two also found "an almost perfect match with other Roman

camps", like those built around the hilltop site of Masada, a fortress besieged by the Romans around AD 73. They shared the images with Tepper and his collaborator, who carried out remote-sensing of the site at Tel Megiddo, including ground-penetrating radar and electromagnetic surveys. Subsequent excavations revealed Roman-period coins, pieces of armour and roof tiles stamped with insignia of the sixth legion: it was definitely their camp.

As for the dating of artefacts, Cline rattles through radiocarbon and potassium-argon analysis, rehydroxylation, pottery typology, thermoluminescence and dendrochronology. However, he stresses, archaeologists must admit "a willingness to acknowledge that none of it is fixed in stone".

For example, rehydroxylation can estimate the age of pottery on the basis of the rate at which it absorbs water after its original firing. But when it was applied to a medieval brick from the UK city of Canterbury, it gave an age of about 66 years. The brick turned out to have been accidentally re-fired when Canterbury was bombed in the second world war.

As for the question of who keeps what, finders are no longer keepers. "Not only don't I get to keep what I find," observes Cline, "I don't think that other people should collect such items either." The consensus among scholars, he says, is that there is a direct correlation between private collecting and the looting of ancient sites – as the recent destruction of ancient Syrian sites by ISIS shows so painfully.

It is difficult to disagree. And yet, how very much poorer would the world's great archaeological museums be without the past donations of private (and often none too scrupulous) collectors. ■

Andrew Robinson is the author of *The Indus: Lost civilizations*

Go at throttle up

NASA's backroom boys get their moment, says **Paul Marks**

Mission Control: The unsung heroes of Apollo, directed by David Fairhead, download on iTunes, stream, or watch at cinemas in the US from 14 April

"Go."

"No go."

"We have lift-off."

"Go for trans-lunar injection."

This evocative and strangely reassuring jargon of the NASA mission controller flows so easily, it's hard to think it had to be invented. But it did, and Chris Kraft is the person largely credited with the lexicon and the life-critical procedures behind it.

Kraft had wanted to be a baseball player, but ended up a flight researcher at the National Advisory Committee for Aeronautics. In 1958, after the Sputnik launch kicked off the space race, NACA became NASA – and Kraft was charged with working out its mission control operations from scratch.

His name is unfamiliar because

The jargon of mission controllers doesn't sound like it was invented

the Apollo moon shots seemed to be choreographed by Gene Kranz, the waistcoat-wearing flight director with a military buzz cut. But Kranz's visibility owed more to Kraft being moved upstairs by the time TV cameras arrived.

Now the contributions of Kraft and his team of flight controllers have been brought into relief in *Mission Control*, a beautifully shot documentary by three space-flight film veterans: director

"Flight-testing the plane that broke the sound barrier provided the model for space mission control"

David Fairhead and producers Keith Haviland and Gareth Dodds.

Interviewing former controllers including Kraft, who is now 93, has yielded fascinating moon mission reminiscences and tales of astonishing teamwork under life-threatening pressures. And Kranz pays due credit in the film to Kraft as his mentor and the brains behind mission control.

The film starkly underscores the magnitude of Kraft's task. With no satellites or GPS, he had to work out how NASA could track, monitor and communicate with a spacecraft circling Earth at 5 miles per second.

At NACA, Kraft and his colleagues had flight-tested the Bell X-1, the plane that was the first to break the sound barrier in level flight. Ground control had used radar to track the plane and radio telemetry to monitor its flight performance, as well as the health of pilot Chuck Yeager. This, says Kraft, was his model – but on a scale requiring a network of ground-based dishes and radar tracking girdling the planet.

NASA's first human space-flight programmes – Mercury and Gemini – went well, but then three Apollo 1 astronauts died in a launch-pad fire in January 1967. The deep regret the mission controllers express, and the way they describe the danger facing the crew (the system just wasn't ready) is heartbreaking. But the 20-month hiatus let NASA re-engineer the Apollo capsule and its procedures. Without it, the US wouldn't have got to the moon.

Unsung space-flight heroes are popular right now: the Oscar-nominated *Hidden Figures* lauded the talented black women who computed rocket trajectories for Project Mercury but got no credit. And, according to President Richard Nixon, some 400,000 people helped put Neil Armstrong's boots on the moon. So we can expect to see more such stories. Bring them on – or, as mission control might say, go at throttle up. ■

NASA

Paul Marks is a technology, aviation and space-flight writer

Teeming with death

A dying neurosurgeon, the zoo that is the human body, and fighting AIDS. The 2017 Wellcome book prize shortlist is dramatic and diverse

Mend the Living *by Maylis de Kerangal, MacLehose Press*
Thomas Remige runs an organ donation unit. On the back of his office door is taped a line from a play he has never read: "Bury the dead and mend the living." Found in a newspaper left lying around in a laundromat, it is "the golden ticket in the chocolate bar" of his life. This novel recounts, beat by beat over 24 hours, a heart transplant in the unit. Everyone involved, from the medical staff to the dying donor and his family, has some equally precarious hold on the world, cementing it with whatever they have to hand. If asked, they might call it "interest", or "training", or "technique", or "skill", or "protocol". The reader will see it for what it really is: courage.

I Contain Multitudes: The microbes within us and a grander view of life *by Ed Yong, The Bodley Head*
In an over-sanitised world, it can feel disgusting to see ourselves as a zoo. Yet that is what we are, existing in fabulous symbiosis with trillions of microbes, fellow travellers from birth to death. And despite the germ model of Louis Pasteur, the microbial majority neither harms nor benefits us. Ed Yong explains all in a confident debut, its title drawn from Walt Whitman's poem *Song of Myself* (but as Yong writes, it's not so much "I contain multitudes and more that I am multitudes"). Through his lively narrative, we discover the microbiome, that giant interconnected microbial web which shapes all living creatures in myriad ways. Among the research Yong details is work that may prove key in understanding autism. When pregnant mice were injected with a substance that triggers an immune response rather as a viral infection would, their offspring grew into anxious, easy-to-startle adults with repetitive behaviours. When the adults were fed a particular gut bacterium, however, some of this was reversed. Recent work on injecting gut microbes from kids with autism into mice had the rodents exhibiting the same repetitive behaviours. What we can draw from this is uncertain right now, but it's all part of Yong's "grander view of life".

When Breath Becomes Air *by Paul Kalanithi, The Bodley Head*
A neurosurgeon with terminal lung cancer writes here about his own dying – and one of the oddest discoveries he shares is the fact that after his diagnosis, he has to live an entirely different life. Who knew that a massively truncated future would inflate to such intimidating proportions? You're finished, so who can you be in the time you have left? Kalanithi's own answer is contained in this essential book.

How to Survive a Plague: The story of how activists and scientists tamed AIDS *by David France, Picador*
"Rare Cancer Seen in 41 Homosexuals" ran a headline in *The New York Times* of 3 July 1981. The image of it in David France's insider book on AIDS, death and the fightback conjures the blissful ignorance of the time. The ensuing loss of innocence makes for an emotionally exhausting read. Researchers checking stored blood from 1982 found 42.6 per cent of gay men in San Francisco and 26.8 per cent in New York already carried the virus. Millions lived in fear. Yet somehow, through many false dawns, scientists and activists battled (sometimes each other) to find treatments. By 2013, the global death toll was as high as 40 million. By 2015, a similar number were living with HIV. A heartbreaking tale, brilliantly told.

The Tidal Zone *by Sarah Moss, Granta*
"There are no premonitions," observes the father of a 15-year-old girl who, for a while, and for no earthly reason, has stopped breathing. "The fact that you are eating a barely acceptable sandwich… doesn't mean that you are not in the interval between losing everything you take for granted and finding out that you have lost it." The strategies we use to hold ourselves together in the waiting areas of intensive care aren't all healthy, and they have consequences, as this novel explores. "From now on," Sarah Moss writes, "life is a matter of mitigation."

The Gene: An intimate history *by Siddhartha Mukherjee, The Bodley Head*
After a rather pedestrian account of the history of genetics, *The Gene* comes alive in its second half, focusing on the past three decades of discovery in medical genetics, with examples from the author's family. Ethical issues associated with recent developments in genetic testing and, increasingly, the potential for genetic treatment, are explored in terms so simple the least informed reader will learn much, although the rest of us will be slowly driven up the wall. ■

THOMAS S.G. FARNETTI/WELLCOME

The winner will be revealed on 24 April, with coverage on newscientist.com. Reviews by Culture's Liz Else and Simon Ings, plus Matthew Cobb, University of Manchester, UK

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Send curriculum vitae and names and addresses of three references to **Dr. Jonathan H.** Jaggar, Maury Bronstein Endowed Professor of Physiology, Department of Physiology, University of Tennessee Health Science Center, 894 Union Avenue, Memphis, TN 38163, USA.
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EDITOR'S PICK

As a nurse I never had the guts to speak out

From Linda Shields, Bathurst, New South Wales, Australia

Someone has more courage than me! Clare Wilson reports a new programme, "Fed is Best", designed to ensure that babies whose mothers have trouble breastfeeding do not end up dehydrated and jaundiced (18 March, p 25). For so long, the "baby friendly hospital" initiative has been the basis for advice about feeding a new baby. It has unintended consequences, like so many well-intentioned interventions.

"Fed is Best" is anathema to many who believe that all women can, and should, feed their baby exclusively on breast milk. This dogma is so strong that I, as a paediatric and child health nurse, have never had the guts to say what I really believe – that not all women can breastfeed, nor should they be coerced to do so.

Mothers carry a burden of guilt when they decide to pick up the bottle and formula. It is well known that breast milk is best for babies, but surely, when this isn't going to be possible, the mother's mental well-being, bonding with her baby, and mother and baby's physical health are more important than dogma.

Be careful what you wish for with alliances

From Bob Cory, Altrincham, Cheshire, UK

Owen Gaffney is undoubtedly right when he suggests that cheap, clean energy would send the Russian economy into a death spiral (25 March, p 24). So Vladimir Putin favouring Donald Trump as president of the US makes superficial sense.

But Trump's clear intention is to reduce energy prices by promoting fracking, which is hardly in Russia's short-term interests. And in the longer term Trump will be gone.

While on the subject, it may be that Trump's "admiration" for Putin looks positive for Russia: but which would you rather have – a predictable "enemy" or a highly unpredictable "friend" who is rearming? The 1939 German-Soviet Treaty of Friendship, Cooperation and Demarcation didn't go too well. Be careful what you wish for.

From Steve Swift, Alton, Hampshire, UK

It seems to me that there is a mechanism by which Donald Trump can be used to good effect to reduce the scepticism over global warming. It just needs a few helping hands in the media.

Every time there is an event that is palpably caused by global warming, our friends in the media will report it along these lines: "This is not caused by Global Warming, as Donald Trump will tell you. And Donald Trump is an honourable man."

As I recall from my English Literature classes, repeating stuff like this had a profound effect on Brutus in William Shakespeare's *Julius Caesar*.

"Do I need to bring two doves to a temple when I get my period, since we're going Old Testament?

Ali Katzenstein responds to news that it is getting harder to access sexual health services in the UK (8 April, p 7)

And we're in desperate need of some profound effects if we're all to prosper.

Cannibalism may have looked different then

From Julian Ash,
Canberra, Australia
Colin Barras thinks it paradoxical that Neanderthals with a largely vegetarian diet may have been eaten by cannibals (11 March, p 9). There have been various reasons and targets for cannibalism.

Forty years ago, an old man living among swamps in southern New Guinea commented to me that "if you eat a diet of sago every day, then meat is welcome, including people". He said that cannibalism had ceased, but in his youth, early last century, the typical occasional victim was an unrelated woman or child on their own, not warriors killed in battle.

Cannibalism may seem unpalatable to people now, but Neanderthals subsisting on wild plants and fungi may have viewed strangers as desirable meat.

Quantum socks are more tangled than that

From Paul Dormer,
Guildford, Surrey, UK
Brian Horton hasn't quite got there with his sock analogy for quantum entanglement (Letters, 1 April). The thing with quantum entangled particles is that there are two ways to perform the measurement of the entangled property – up/down or left/right to put it simply – and you have to decide in advance which measurement to make.

So if you have four quantum entangled socks, two red and two green, and you get dressed in the dark, it all depends on which foot you look at first.

If you decide to look at your left foot first and you have on a red sock, then you know your partner, if they look at their left foot, has on a green sock. Similarly, if you both look at your right foot. But if you look at your left foot and your partner looks at their right foot, then you can make no prediction. Fifty per cent of the time you will have on socks of the same colour.

Furthermore, once you have looked at one foot, if you look at your other foot, the sock there will have mysteriously turned grey, as will your partner's.

Point that sexism-meter at yourselves, please

From Claire East,
Haddington, East Lothian, UK
I was interested to read about gender bias in films being laid bare by software (18 March, p 16). Then I turned to read about what's up with gravity (p 28). This would appear to show this effect in other areas: your graphic for the article shows a male predominance of three to one.

How to remove a tick safely from your skin

From Ian Backhouse,
Gosport, Hampshire, UK
I was fascinated by your article on the increasing distribution of Lyme disease (1 April, p 20). But I would take issue with your advice on what to do if you find a tick. Using tweezers could squeeze the tick body and inject the contents of its gut into your skin. This could inject you with the disease-causing bacterium from the gut.

A better method is to use a tick remover, as found in pet shops. Failing this, a loop of very fine thread should be passed between your skin and the body of the ›

tick – easier said than done – then tightened so that the body is not squeezed in the removal process.

The editor writes:

■ The US Centers for Disease Control suggests you use fine-tipped tweezers to grasp the tick as close to the skin's surface as possible... and not twist or jerk the tick (bit.ly/NStweezers). Your methods may be safer still.

Soya might protect against breast cancer

From Eric Kvaalen, Les Essarts-le-Roi, France

You say that some studies have suggested that soya milk may increase the risk of breast cancer (11 March, p 32). Research in mice published in February shows that the drug tamoxifen was more effective if they had been fed soya phytoestrogen all their adult lives rather than starting after tumours had developed.

This may explain the finding that Asian women, who consume lots of soya, have a rate of breast cancer five times lower than that of Western women.

Why not grab a passing moon for your own?

From Bill Robinson, Slough, Berkshire, UK

It is interesting that each observed Trans-Neptunian Object seems to have a moon of its own (18 March, p 19). You state that "these moons probably formed when a large rock collided with the parent body and the debris coalesced in orbit". That is a plausible way to form a moon, but is it not as likely that, in the "crowded, chaotic past" you mention, these TNOs grabbed a passing body for a moon?

The habitable zone of planets in locked orbits

From Martin Gregorie, Harlow, UK

Leah Crane reports that three planets of the star TRAPPIST-1 are supposed to be within its habitable zone (18 March, p 14). But what about the effect of tidal locking on the habitability of such planets, where one side of the planet always faces the star?

Is it assumed that planets in the zone are rotating fast enough to keep the diurnal temperature variation within a reasonable range? If the planet is in the outer half of the zone, would there be a sea or lakes at the centre of the sunlit hemisphere, and hence the possibility of life? Or would all the water travel as vapour to the cold trap on the dark side and freeze?

You could end up with a bone-dry desert in the middle of the sunward side, and a wet ring, possibly harbouring some sort of life, in the twilight zone between the desert and a polar icecap in the middle of the dark side.

A personal reason to be concerned about viruses

From Cedric Mims, Canberra, Australia

Congratulations on that most excellent article about plagues (25 February, p 28). I was a bit disappointed that the influenza virus didn't get more space, since it has killed about as many people as the Black Death.

The sinister-sounding names and origins of the World Health Organization's list of nine priority pathogens makes them newsworthy. You are right to focus on that key feature, the genetic sequences associated with person-to-person spread.

I have worried and wondered whether these nasties would ever acquire such sequences since my first encounters with the West Nile, Zika and chikungunya viruses, all discovered in the Uganda laboratory where I began work in 1953.

Unfortunately, I accidentally infected myself with Rift Valley Fever virus – but luckily this meant no more than an uncomfortable few days in hospital and it didn't spread to anyone else.

How big is that heart in blue whales?

From John Atkinson, Douglas, Isle of Man

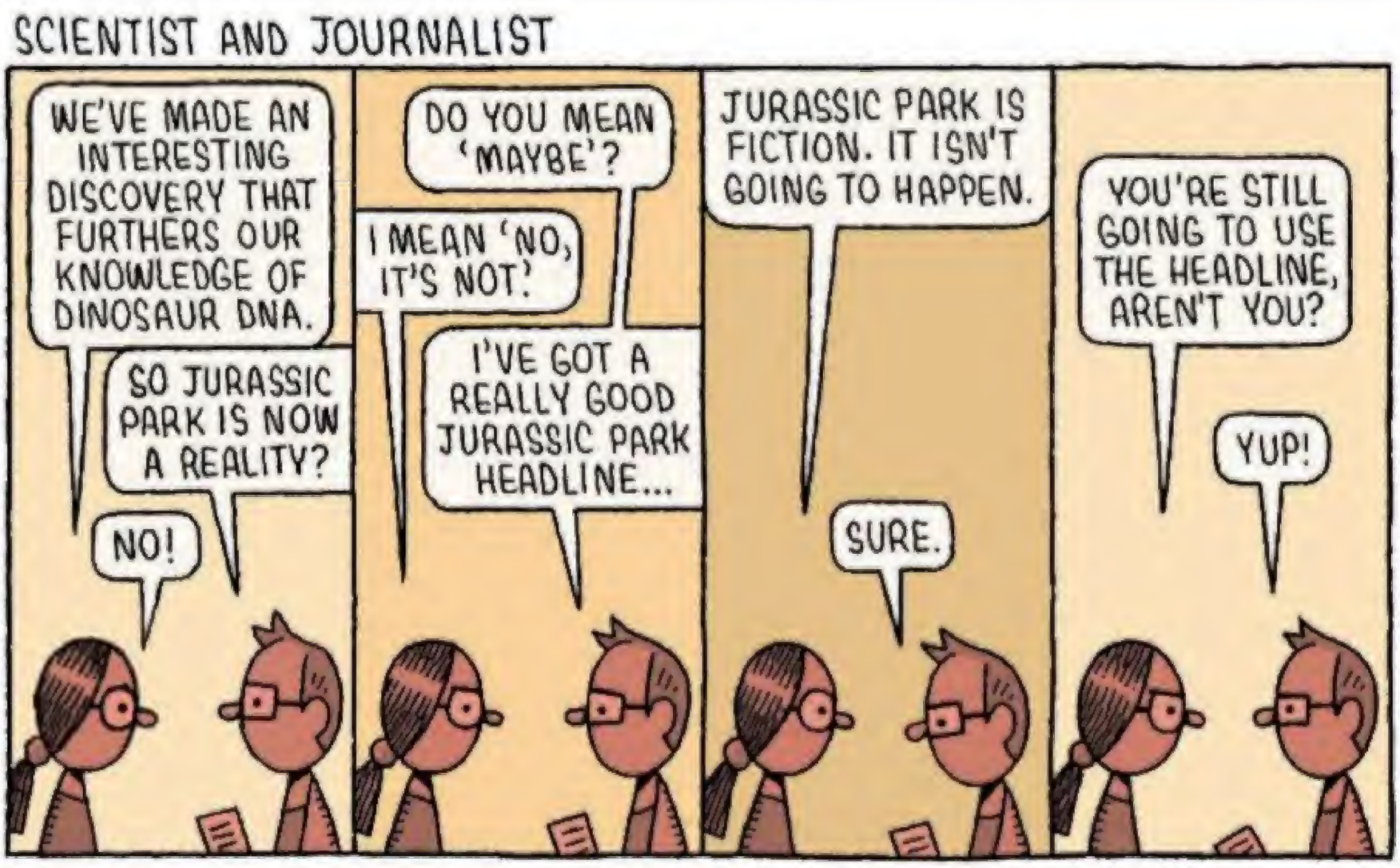
Sandrine Ceurstemont mentions the small size of the blue whale's heart (18 March, p 44). This suggests to me that some of the pumping work may be done elsewhere. The movement of the tail is rhythmic: I wonder if it has the effect of squeezing the blood vessels and thus augmenting the action of the heart.

Reeling and writhing against poaching

From Roger Calvert, Ulverston, Cumbria, UK

You report on the use of artificial turtle eggs to track poachers (25 March, p 22). Could these be linked to the mock turtle in Lewis Carroll's *Alice's Adventures in Wonderland*? Could they be made into soup, as an alternative to the recipe at bit.ly/MockTurtleSoup?

TOM GAULD



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Helping the young with tech

From mobile computing to augmented reality to artificial intelligence, technological growth has exploded since the turn of the 21st century. Keeping up can be tough, even for the most dedicated of enthusiasts.

There's a common assumption that young people have the knowledge and confidence to use technology with ease. The reality is very different. *Slipping Through the Net*, a report by the London School of Economics, Samsung and The Prince's Trust, found that 40 per cent of disadvantaged young people in the UK had low levels of online skills, leaving them vulnerable to opportunists, while 38 per cent felt that no one or almost no one could be trusted in the digital space. The report highlights the fact that these young people risk being left behind digitally.

The Prince's Trust is dedicated to helping every young person develop the skills and confidence they need to succeed both online and offline. We are embedding digital learning across our programmes and increasing training around softer skills to enable the next generation to use technologies safely and effectively. In a groundbreaking move, we are also launching an online learning platform and e-mentoring service. This will enable us to increase the number of young people we work with and give them greater access to work experience, training and job opportunities.

We hope government, businesses and other organisations will join us in developing new solutions to ensure that young people, whatever their background, can navigate the digital world without fear and make the most of their chances in life. With technology providing so many opportunities, no one should be left behind.

We are currently on the lookout for volunteer e-mentors to support our young people, channel their energies and empower them to fulfil their aspirations. **Richard Chadwick, programmes and development director, The Prince's Trust**

For more information on e-mentoring, visit **princes-trust.org.uk/volunteer**

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PAUL MCDEVITT

THE US administration is keen to address the impact of climate change on American businesses, principally the way in which environmental regulations are impinging on their profit margins. Budget proposals unveiled by President Trump would slash funding for climate research.

Thoughtfully, US politicians are eager to fill in the looming knowledge gap with their own free-spirited theories. National Public Radio reports that Republican senator Scott Wagner told constituents in Pennsylvania "I haven't been in a science class in a long time" – at which point any sensible politician would have stopped talking – "but the Earth moves closer to the sun every year, you know, the rotation of the Earth."

Adding to his alarming heliocentric model, Wagner said, "We have more people. You know, humans have warm bodies. So is heat coming off? Things are changing, but I think we are, as a society, doing the best we can."

Feedback can only speculate that the more researchers we send to the Arctic, the faster it seems to melt. Coincidence?

IS EARTH spherical, like a basketball, or flat like the court the game is played on? The jury is still out for several US sports stars, who voiced their doubts about geosphericism last month (1 April). "I thought you'd like to know about the Flat Earth International Conference 2017," writes Bob Lang. "Apparently delegates will be arriving from around the world to get there."

Held in North Carolina this November, the Flat Earthers meeting features many keynote speakers you may recognise from rambling YouTube videos filled with badly drawn diagrams and the palpable frustration of not being taken seriously. That will end soon though, because the conference has thrown down the gauntlet to the world of science.

A Facebook page headed by a description of the minutiae of "Satan's globe Earth lie" (to wit: "We evolved from primordial soup. We are specks in the universe. Some people are more valuable than others.") brings news that niche imprint Sacred Word Publishing is offering the oddly specific sum of $8250 to anyone who can successfully demonstrate that Earth is round, using two original experiments. Yes, Earth may stand still, but the burden of proof can easily be hoisted onto your opponent's shoulders.

"It can't be beyond the wit of Feedback readers to pick up this particular challenge," says Bob. And not only will this prove that Satan's globe Earth lie is a reality after all, it will demonstrate some people really are worth more than others – specifically, $8250 more.

TAKING a pragmatic approach to the problem of spelling words out with single letters from the periodic table (18 February), Andy Ward spies an opportunity. "The periodic table contains no element beginning with J or Q," he says, "I suggest that when element 119 is made it should be named quasimodium." Perhaps an opportunity for researchers at the University of Notre Dame in Indiana?

Element 120, meanwhile, "should be called janskium after Karl Jansky the radio-astronomer, as it would appear directly below radium." Which would leave us just 10 letters short of an alphabetically complete periodic table, but promisingly, only four short of spelling "ISLAND OF STABILITY".

KLEE IRWIN is a man who made a small fortune selling health supplements such as "Colon Clear", although not as much as he would have were it not for a 2011 lawsuit that fined his company $2.65 million for false and misleading advertising, plus the small matter of selling a supplement that contained 14 times the legal limit of lead.

A rehabilitated Irwin has now pivoted into theoretical physics, a field in which fantastical claims with scant supporting evidence can still boast a degree of respectability. His Quantum Gravity Research group is seeking to build a new, first-principles unified theory of everything they call Emergence Theory, "to unify, through mathematical and scientific rigor, the theory of relativity, quantum mechanics... and consciousness."

Presumably frozen out by mainstream research funders, Irwin is calling for donations via the Quantum Gravity Group's web page – after all, particle colliders don't build themselves. But does the world need a new theory of everything? The letters inbox at *New Scientist* receives at least one a week – perhaps it could do with a dose Colon Clear.

TAKEN aback by the creative uses for afterbirth (1 April), Frank Cross writes to say "When I was a lad, the placentas were fed to matron's cat." This strikes us as both practical and economical. But Feedback isn't sure that a cat with a taste for human flesh is the best pet to have strolling freely around a maternity ward.

JOHN HOW is left puzzling over an information card attached to his new laptop adaptor. "Electricity travels at 300,000 kilometres per second," it tells him. "If we could move that fast, we'd be able to race around the world eight times in the time it takes to turn on a light." If we could move around the world that fast, why would we need lights anyway?

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Something smells fishy about Marks & Spencer's Coastal Walk scented candle, with its "fragrance of fresh coastal air", says Max Glaskin. "Maybe it's the fact that it is also "harmful to aquatic life"

Milk's mucky mass

My sister claims to know when milk has gone off because "the carton feels heavier than it should". Could she be right? And if so, why?

■ The heavy carton effect is likely to be an illusion. Milk contains the bacterium *lactobacillus acidophilus*, which breaks down the sugar lactose present in milk into lactic acid, which makes milk taste sour, or "off".

The lowered pH of soured milk causes milk proteins, such as casein, to become denatured – their usual folded conformation is unwound and the resulting loose strings of protein bond together, forming dense lumps called curds. These sit in the watery whey left behind. This alters the consistency of the milk and can make holding a carton of it feel oddly different.

In particular, the uneven density of curds and whey means that when the milk sloshes around in the carton, the carton can momentarily feel "heavier" than expected, based on our experience of handling fresh milk with its even density, despite there being no actual difference in mass for the same volumes of fresh and curdled milk.

Sam Buckton
Churchill College
University of Cambridge, UK

■ Your correspondent's sister can't detect an increase in mass because milk is nine-tenths water and there's nothing to add mass. What she might detect is a change in the tautness of the carton or in the milk's viscosity.

If the carton is airtight, internal pressure from bacterial gas excretion would make the carton feel more "solid". Alternatively, milk changes in different ways depending on the flora involved: if it has gone clumpy, the viscosity of the rest of the fluid will be lower, but if it is ropey or gel-like, then fluid viscosity will increase. So what she could be detecting is the difference in the swirling and sloshing of the milk.

Is this plausible? Water has a viscosity of 1 millipascal-second (mPa s) at 20°C, full milk is 2 or 3 mPa s, buttermilk may be between 45 and 80 mPa s, and sour cream is 100,000 mPa s. Informal testing shows people can tell full milk from water if handling identical cartons of both. So if your sister handles milk cartons every day then she might be able to detect that milk has begun to thicken or clump.

Ron Dippold
San Diego, California, US

In-flight entertainment

The Last Word has been discussing how and when Earth's magnetic field flips. I know the odds are huge of such a flip in my lifetime, but what would happen to an aircraft in flight if north and south swapped ends?

■ If Earth's magnetic field flipped while you were flying in an aircraft, you wouldn't notice anything unusual, for two very good reasons.

First of all, commercial planes don't use magnetic compasses for navigation. Instead, they use GPS for positioning and guidance, which is so accurate that an aircraft can land without pilot intervention. Even before the arrival of GPS, inertial navigation systems were used, which determine the path of an aircraft by measuring its acceleration along multiple axes, and computing its position from that.

The second reason why you won't notice anything is that the magnetic field doesn't flip immediately. Instead, it slowly changes over a period of 1000 years or more. The magnetic poles are always moving around; usually they move very slowly, whereas during a reversal they just drift further and faster than usual, until eventually they settle in a reversed polarity.

Studies of old lava flows have shown that the magnetic field can drift as much as 6 degrees per day during a reversal period. However, even this extreme case would amount to only 3 degrees over a 12-hour flight.

As for aircraft communications, Earth's magnetic field has very little effect on that too. It is possible that, as the poles drift, a plane might find itself under an aurora in an unusual location away from the poles. Even then, because the drift is slow and because satellites check for the solar storms that cause auroras, the pilot would almost certainly have advance warning.

Herman D'Hondt
Newtown, New South Wales, Australia

This week's questions

MIDNIGHT CHORUS
On the radio I heard complex birdsong that had been recorded at midnight in summer in Finland. The Last Word has discussed what life is like for humans in polar regions, but how does wildlife cope with 24 hours of daylight?
John Philpott-Howard
London, UK

LET'S BE BLUNT
How do metal blades in wet shavers lose their sharpness so easily on human hair and how can I avoid this?
Graham Thompson
Cumbria, UK

EVER DECREASING CIRCLES
Solar systems orbit the centre of their galaxies. Planets orbit stars. Moons orbit planets. Does anything orbit moons? If not, why not?
John Farrant
Swanbourne, Buckinghamshire, UK

CANINE CLAMOUR
Why is it that a dog that barks for a whole weekend, practically non-stop, doesn't lose its "voice"?
David Lockyer
Waterlooville, Hampshire, UK

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Professor Dame Carol Robinson
2015 Laureate for United Kingdom
By Brigitte Lacombe
For Women in Science
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